COMPARATIVE STUDY OF CHANGES IN PHARYNGEAL AIRWAY DIMENSION AND HYOID BONE POSITION FOLLOWING NONSURGICAL ORTHODONTIC TREATMENT IN CLASS I AND CLASS II SUBJECTS

Dissertation Submitted to

THE TAMIL NADU DR. M.G.R. MEDICAL UNIVERSITY

In Partial fulfilment for the degree of

MASTER OF DENTAL SURGERY

BRANCH - V
ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS
APRIL – 2013

CERTIFICATE

This is to certify that the dissertation entitled "***COMPARATIVE STUDY OF CHANGES IN PHARYNGEAL AIRWAY DIMENSION AND HYOID BONE POSITION FOLLOWING NONSURGICAL ORTHODONTIC TREATMENT IN CLASS I AND CLASS II SUBJECTS***" done by **Dr. N.M.VIJAYKUMAR** Post graduate student (M.D.S), Orthodontics (branch V), Tamil Nadu Govt. Dental College and Hospital, Chennai, submitted to the Tamil Nadu Dr. M.G.R. Medical University in partial fulfilment for the M.D.S. degree examination (April 2013) is a bonafide research work carried out by him under my supervision and guidance.

Guided By

Dr. M.C.SAINATH M.D.S.,

Professor and Head of the Department,

Dept. of Orthodontics,

Tamil Nadu Govt Dental College & Hospital,

Chennai - 600 003

Dr. K.S.G.A. NASSER, M.D.S.,

Principal,

Tamil Nadu Govt Dental College, & Hospital,

Chennai - 600 003.

DECLARATION

I, **Dr. N.M.VIJAYKUMAR** , do hereby declare that the dissertation titled "**COMPARATIVE STUDY OF CHANGES IN PHARYNGEAL AIRWAY DIMENSION AND HYOID BONE POSITION FOLLOWING NONSURGICAL ORTHODONTIC TREATMENT IN CLASS I AND CLASS II SUBJECTS**" was done in the Department of Orthodontics, Tamil Nadu Government Dental College & Hospital, Chennai 600 003. I have utilized the facilities provided in the Government Dental College for the study in partial fulfilment of the requirements for the degree of Master of Dental Surgery in the speciality of Orthodontics and Dentofacial Orthopaedics (Branch V) during the course period 2010-2013 under the conceptualization and guidance of my dissertation guide, **Professor Dr. M. C. Sainath, MDS.**

I declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission from the Tamil Nadu Government Dental College & Hospital.

I also declare that no part of this work will be published either in the print or electronic media except with those who have been actively involved in this dissertation work and I firmly affirm that the right to preserve or publish this work rests solely with the prior permission of the Principal, Tamil Nadu Government Dental College & Hospital, Chennai 600 003, but with the vested right that I shall be cited as the author(s).

Signature of the PG student **Signature of the HOD**

Signature of the Head of the Institution

ACKNOWLEDGMENT

My sincere thanks to **Dr. K.S.G.A. NASSER, M.D.S.**, Principal, Tamil Nadu Government Dental College and Hospital, Chennai-3, for his kind support and encouragement.

I express my deep sense of gratitude and great honour to my respected guide, **Professor Dr. M.C.SAINATH M.D.S., Head of the Department**, Department of Orthodontics and Dentofacial orthopaedics, Tamilnadu Govt. Dental College and Hospital, Chennai-3, for his patience guidance, support and encouragement throughout the study.

I owe my thanks and great honour to **Dr. G. VIMALA M.D.S, Professor**, Department of Orthodontics and Dentofacial Orthopaedics, Tamilnadu Govt. Dental College and Hospital, Chennai3, for helping me with her valuable and timely suggestions and encouragement.

I owe my thanks and great honour to **Dr.S.PREMKUMAR M.D.S, Professor**, Department of Orthodontics and Dentofacial Orthopaedics, Tamilnadu Govt. Dental College and Hospital, Chennai3, for helping me with his valuable and timely suggestions and encouragement.

I am grateful to **Dr.B.BALASHANMUGAM, M.D.S., Assistant Professor**, Department of Orthodontics, Tamil Nadu Government Dental College and Hospital, Chennai –3 for his support and encouragement.

I am grateful to **Dr. USHA RAO, M.D.S., Assistant Professor**, Department of Orthodontics, Tamilnadu Government Dental College and Hospital, Chennai-3 for her support and encouragement.

I am grateful to **Dr. K. USHA, M.D.S., Assistant Professor**, Department of Orthodontics, Tamil Nadu Government Dental College and Hospital, Chennai –3 for her support and encouragement.

I thank **Dr. R. RAVANAN M.Sc., M.Phil., Ph.D., Professor of Statistics**, Presidency College, for helping me with the Statistics in the study.

I take this opportunity to express my gratitude to my friends and colleagues for their valuable help and suggestions throughout this study.

I offer my heartiest gratitude to my family members for their selfless blessings.

I seek the blessings of the Almighty God without whose benevolence; the study would not have been possible.

<u>TRIPARTITE AGREEMENT</u>

This agreement herein after the “Agreement” is entered into on this day............... day of December 2012 between the Tamil Nadu Government Dental College and Hospital represented by its **Principal** having address at Tamilnadu Government Dental college and Hospital, Chennai-03, (hereafter referred to as , ’the college’)

And

Dr. M. C. Sainath aged 55 years working as professor at the college, having residence address at Block ‘U’, Door no 11,4th main road, Annanagar, Chennai 600040, Tamilnadu (herein after referred to as the ‘Principal investigator’)

And

Dr. N.M.VIJAYKUMAR aged 28 years currently studying as postgraduate student in department of Orthodontics in Tamilnadu Government Dental College and Hospital (herein after referred to as the ‘PG/Research student and co- investigator’).

Whereas the ‘PG/Research student as part of his curriculum undertakes to research on “C***omparative study of changes in pharyngeal airway dimension and hyoid bone position following nonsurgical orthodontic treatment in class I and class II subjects***.” for which purpose the PG/Principal investigator shall act as principal investigator and the college shall provide the requisite infrastructure based on availability and also provide facility to the PG/Research student as to the extent possible as a Co-investigator.

Whereas the parties, by this agreement have mutually agreed to the various issues including in particular the copyright and confidentiality issues that arise in this regard.

Now this agreement witnesseth as follows:

1. The parties agree that all the Research material and ownership therein shall become the vested right of the college, including in particular all the copyright in the literature including the study, research and all other related papers.

2. To the extent that the college has legal right to do go, shall grant to licence or assign the copyright do vested with it for medical and/or commercial usage of interested persons/entities subject to a reasonable terms/conditions including royalty as deemed by the college.

3. The royalty so received by the college shall be equally by all the parties.

4. The PG/Research student and PG/Principal Investigator shall under no circumstances deal with the copyright, Confidential information and know – how generated during the course of research/study in any manner whatsoever, while shall sole vest with the manner whatsoever and for any purpose without the express written consent of the college.

5. All expenses pertaining to the research shall be decided upon by the principal investigator/Co-investigator or borne sole by the PG/research student.(co-investigator)

6. The college shall provide all infrastructure and access facilities within and in other institutes to the extent possible. This includes patient interactions, introductory letters, recommendation letters and such other acts required in this regard.

7. The principal investigator shall suitably guide the student Research right from selection of the Research Topic and Area till its completion. However the selection and conduct of research, topic and area research by the student researcher under guidance from the principal investigator shall be subject to the prior approval, recommendations and comments of the Ethical Committee of the college constituted for this purpose.

8. It is agreed that as regards other aspects not covered under this agreement, but which pertain to the research undertaken by the student Researcher, under guidance from the Principal Investigator, the decision of the college shall be binding and final.

9. If any dispute arises as to the matters related or connected to this agreement herein, it shall be referred to arbitration in accordance with the provisions of the Arbitration and Conciliation Act, 1996.

In witness whereof the parties hereinabove mentioned have on this the day month and year herein above mentioned set their hands to this agreement in the presence of the following two witnesses.

College represented by its **Principal** **PG Student**

Witnessess **Student Guide**

1.

2.

CONTENTS

List of tables

List of colour plates

Abstract

Background: Pharyngeal airway dimensions, narrowing of pharyngeal passage and hyoid bone positions are of interest in orthodontics .It is evident that there exists a mutual correlation between position of the hyoid bone, volume of pharyngeal airway and dentofacial structures. Therefore it is relevant to evaluate the changes in nasopharyngeal airway and hyoid bone position in subjects with moderate dentofacial deformities, who had orthodontic treatment. This retrospective, analytical cephalometric study had been undertaken to investigate correlation in skeletal Class I and skeletal Class II subjects who had undergone non-surgical orthodontic treatment.

Aim: The aim of this study was to evaluate and compare the changes in pharyngeal airway dimension and hyoid bone position following non-surgical orthodontic treatment in Class I and Class II dentofacial deformities.

Materials and methods: 40 sets (pre & post treatment) of lateral cephalograms of subjects (20 skeletal Class I & 20 skeletal Class II malocclusion) were analysed. The control group consisting of 20 lateral cephalograms of subjects with normal occlusion and good visibility of hyoid bone were used .All cephalograms were taken in natural head position, with PLANMECA PM 2002 CC PROLINE machine. All the radiographs were scanned with CANON D520 MF scanner and digitized. A Cephalometric analysis software AX CEPH version 2.3.0.74 was used to analyse the radiographs.

Results: Pretreatment hypopharynx area was significantly constricted in both Class I and Class II groups with highly significant reduction (p value < 0.001) in Class II groups in comparison with normoocclusion group. In Class I malocclusion group there was a significant decrease in overall upper airway dimensions, with more reduction in glossopharynx and hypopharynx areas following orthodontic treatment with only velopharynx and glossopharynx areas approximating to the values of the normoocclusion group. In Class II malocclusion the glossopharynx and hypopharynx areas were widened significantly, still the hypopharynx area was not widened to the level of normoocclusion group. After treatment the hyoid was retracted postero inferiorly in Class I group and in Class II group the hyoid bone was shifted anterosuperiorly. Still the hyoid position was not approximated to that of normoocclusion group. There was no statistically significant (p value > 0.05) sexual dimorphism in both pharyngeal airway dimensions and hyoid bone positions in all three groups.

Conclusion: There is a definite difference in pharyngeal airway dimension and hyoid bone position in different malocclusions. It was evident that Non-surgical orthodontic treatment had a significant influence on the pharyngeal airway dimensions and hyoid bone positions in Class I and Class II malocclusion corrections.

Key Words: Pharyngeal Airway, Hyoid Bone, Lateral Cephalograms, Class I & Class II Malocclusion.

Introduction

Pharyngeal airway dimensions and resistance are of interest in orthodontics. Ever since, several studies have indicated a close association between airway dimensions and dentofacial structures[20, 24]. Numerous evidences from cephalometric studies support a link between airway dimensions, hyoid bone positions and maintenance of dentofacial harmony.

The pharynx is a 12–14 cm long musculomembranous tube shaped like an inverted cone [29]. It extends from the cranial base to the lower border of the cricoid cartilage (the level of the sixth cervical vertebra), where it becomes continuous with the oesophagus[73].

The pharynx communicates with the nasal, oral and laryngeal cavities via the nasopharynx, oropharynx and laryngopharynx respectively[45]. The nasopharynx and the oropharynx have significant locations and functions as they form a part of the unit in which respiration and deglutition are carried out. The nasopharynx forming the upper part of respiratory system is connected anteriorly with nasal cavity and posteriorly it extends as oropharynx. The oropharynx extends from the soft palate to the base of epiglottis (from second to fourth cervical vertebra). The laryngopharynx joins the oropharynx at the level of pharyngoepiglottic fold and the hyoid, and then it continues upto the level of the sixth cervical vertebra.

The pharynx is composed of three coats: mucous, fibrous, and muscular**.** The muscles of the pharynx are three circular constrictors and three longitudinal elevators. The constrictors may be thought of as three overlapping cones which arise from structures at the sides of the head and neck and pass posteriorly to insert into a midline fibrous band, the pharyngeal raphe (overlapping has been compared with that of three flower pots placed one inside another)[73]. Its lining mucosa is continuous with that lining the pharyngotympanic tubes, nasal cavity, mouth and larynx [29].

Nasal obstruction due to anatomical variations and pathologies can cause chronic mouth breathing and a number of postural changes, such as open mandibular posture, downward and forward positioning of the tongue, and extension of the head. If these postural changes continue during the active growth stage without any restrictions, over a period of time many dentofacial disorders at different levels of severity can be seen, such as long face syndrome or adenoid facies[51]. Other than these factors there is also the natural anatomical predisposition of narrower airway passages. Skeletal features such as retrusion of the maxilla and mandible and vertical maxillary excess in hyperdivergent patients may lead to narrower anteroposterior dimensions of the airway[75].

Obstructive sleep apnoea is a serious medical problem and may be precipitated by any narrowing of the upper airway caused by external or internal factors. Investigators have reported a steeper mandibular plane angle, shorter mandibular body length and a low hyoid bone position in patients suffering from obstructive sleep apnoea.

Hence pharyngeal study is of importance to both otolaryngologists and orthodontists alike.

According to the Balter's philosophy, Class II malocclusions are a consequence of a backward position of the tongue, due to which the normal respiratory function is impeded and thus resulting in a faulty deglutition and mouth breathing; while Class III malocclusions are due to a more forward position of tongue[28].

The size of nasopharyngeal area is significantly greater in Class I than in Class II malocclusions[20]. Hence a significant interaction is expected to occur between the pharyngeal structures and dentofacial pattern.

The hyoid bone is a horseshoe-shaped bone situated in the anterior midline of the neck between the chin and the thyroid cartilage. At rest, it lies at the level of the base of the mandible in the front and the third cervical vertebra behind[29, 45]. Unlike other bones of neck hyoid does not have any bony articulations. It provides attachments for ligaments, muscles, fascia of cranium and mandible. The two major group of muscles attached to hyoid bone are suprahyoid and infrahyoid muscles. Both suprahyoid and infrahyoid muscles have wide range of actions.

Digastric muscle is one of the suprahyoid muscles increase the antero posterior dimensions of oropharynx during deglutition. The stylohyoid and posterior belly of digastric act together to prevent the regurgitation of food[49].

The hyoid bone plays an important and active part in accomplishing the delicate balance between anterior and posterior muscle tension relative to the occipital condyles, which in turn helps to balance the head as man assumed an upright posture.

It is evident that there exists a mutual correlation between position of the hyoid bone, volume of pharyngeal airway and dentofacial structures. In all types of dentofacial deformities there is a difference in position of dentofacial structures including teeth. Therefore it is relevant to evaluate the changes in nasopharyngeal airway and hyoid bone position in subjects with moderate dentofacial deformities, who had orthodontic treatment. The methods for evaluating pharyngeal dimension in orthodontic practices are limited.

This retrospective, analytical cephalometric study had been undertaken to investigate such correlation in skeletal Class I and skeletal Class II subjects who had undergone non-surgical orthodontic treatment with extraction of four premolar teeth and comparing it with normoocclusion subjects.

AIM AND OBJECTIVES

AIM:

The aim of this study was to evaluate and compare the changes in pharyngeal airway dimension and hyoid bone position following non-surgical orthodontic treatment in Class I and Class II dentofacial deformities.

OBJECTIVES:

- To determine whether the pharyngeal airway dimensions and hyoid bone position were affected by non-surgical orthodontic treatment in skeletal Class I & skeletal Class II subjects.
- To evaluate the pharyngeal airway dimensions and hyoid bone position in normal subjects of South Indian origin.
- To compare the changes of pharyngeal airway dimensions and hyoid bone positions between these groups.
- To determine any sexual dimorphism in the changes of pharyngeal airway dimensions and hyoid bone positions following non-surgical orthodontic treatment in both Class I and Class II groups.

Review of literature

The Pharyngeal airway is composed of 20 or more muscles that are attached proximally to skeletal structures and those size and form are affected by the developing craniofacial skeleton. The oral and pharyngeal regions are said to have a primary function in maintaining a patent airway. This is accomplished by a dynamic musculoskeletal balance. The pharyngeal airway is one of the determinants of anteroposterior relationship of jaws, particularly the mandible; by means of determining the tongue position. Accordingly, the dimensions of pharynx are determined by the position and relation of the maxilla and the mandible. Moss[56] while explaining the functional matrices goes one step further by including the pharynx into the oro-naso-pharyngeal functioning spaces, whose volumetric growth is primary morphogenetic event in facial skull growth. The literature related to the development of pharyngeal airway and hyoid bone position and their association with the various malocclusions has been reviewed here.

Balters[28] (1952) had a unique view as far as the aetiology of the development of malocclusion was concerned. According to his hypothesis, Class II malocclusions were a consequence of a backward position of the tongue which impedes the respiratory function, concomitantly leading to narrower pharyngeal airway and mouth breathing. By the same analysis, he reasoned that Class III conditions are due to a more forward position of tongue and consequently larger pharyngeal airway dimensions.

Allan G. Brodie[2] (1952) discussed the role of musculature in diagnosis, treatment and retention. According to him, the hyoid and the tongue are intimately associated structures and both are positioned in space by a 3 point muscular suspension.

Carmine Durzo et al[14] (1962) studied the growth behaviour of the hyoid bone in relation to other craniofacial structures in a longitudinal cephalometric study. They concluded that the hyoid bone has a stable vertical position in normal individuals, at a level opposite the lower portion of third and upper portion of fourth cervical vertebra. During growth its relative position remains constant when it descends as the cervical vertebrae increase their length and the cranial base and mandible descend and move away from each other. In the mandibular deformity cases the hyoid movements followed closely those of mandibular growth movements and were restricted both anteroposteriorly and vertically. The hyoid movements were also modified as per the demands of maintaining a patent airway.

Reul Bench[74] (1963) carried out an elaborate cephalometric study on the growth of the cervical vertebra as related to tongue; face and denture behaviour. He concluded that, in older ages, the behaviour of the hyoid bone is more consistent to the growth of the cervical vertebrae than chin growth. At 3 years of age the hyoid lies at a level between 3rd and 4th cervical vertebrae and descends to the level of the 4th vertebrae at adulthood. Furthermore the clinical manifestations of open bite are characterized by unusual position and behaviour of the hyoid bone. He noted that in dolichocephalic persons there was a more vertical descent of the hyoid bone than in brachycephalic persons. However the latter was characterized by a more anterior growth shift of the hyoid bone. It was postulated that the descent and retraction of the tongue seemed to offer one explanation of the late crowding that develops in the anterior region of the lower dental arch following orthodontic treatment or in normal untreated cases.

Robert Sloan et al[71] (1967) using cineflurography compared the hyoid movement during deglutition in Class I and Class II patients. They concluded that in Class I malocclusion patients, the hyoid bone was found to be positioned more posteroinferiorly and showed the greatest range of vertical movement during deglutition. It also showed the most limited functional pattern in this group. In Class II patients, the hyoid was positioned more upwards and forwards or anterosuperiorly to the mandible and showed the greatest range during deglutition. The authors confirmed two patterns of hyoid bone movement during deglutition-Circular and Oblique or Elliptical.

Moss[56] (1969) in his functional matrix theory of facial growth, states that the changes in cell size, shape and spatial position, and indeed the very maintenance of all the skeletal units; are always secondary to the primary changes in their functional matrices. He called pharynx as, a part of one of the primary functional spaces – the oro-naso-pharyngeal functioning space (orofacial capsular matrix); and it is the volumetric expansion of these pharyngeal, oral and nasal spaces that causes the translation of all the skeletal units embedded within the orofacial capsule.

Ian Milne and John Cleal[37] **(1970)** evaluated the functional adaptation of orofacial structures in a cineflurographic study. They concluded that the hyoid, the tongue and the mandible worked as an integrated unit. The positional changes of the hyoid bone are characteristics of the integration of numerous structures involved in deglutition. The tongue tip and pharyngeal structures are capable of acting in part, autonomously and the adaptive movements of the hyoid are responsible for the maintenance of an adequate airway.

Gary Cuozzo and Douglas Bowman[27] **(1975)** shed light on the changes in the hyoid bone during deglutition following forced distal positioning of the tongue by a tongue crib. The conclusions suggested that in persons with the hyoid resting close to the mandible, the hyoid bone moved in a posteroinferior direction following crib placement and in persons where hyoid rest position was distant from the mandible, the hyoid bone did not show any positional change following crib placement. They attributed these differences to the limitation of posterior displacement of the hyoid bone in need for maintaining a patent airway.

Garland Hershey.H et al[26] (1976) in their study of Changes in nasal airway resistance associated with rapid maxillary expansion with six boys and eleven girls (between 11 and 14 years of age) who had mouth breathing, concluded that rapid maxillary expansion was not only an efficient method for increasing the width of narrow maxillary arches but also reduces nasal resistance from levels associated with mouth breathing to levels compatible with normal nasal respiration.

David Gobielle and Douglas Bowman[21] (1976) illustrated the hyoid bone and muscle changes in 10 children, 11 to 15 years of age, after distal positioning of the tongue. They concluded the following,

a. The hyoid bone assumed a posteroinferior position in individuals with the rest position of the hyoid bone near the mandible and in individuals with hyoid rest position distant from the mandible, there was no change in hyoid position after distal tongue repositioning.

b. There was no change in hyoid path during deglutition before and after distal tongue positioning.

Proffit[68] (1978) explained that if there was difficulty in breathing due to airway obstruction, the physiologic adaptation that facilitate mouth breathing include a forward posture of head and a lowered position of the mandible with a low and forward tongue posture.

Lee Graber[48] (1978) correlated pre and post treatment hyoid positions after chin cup therapy in 30 individuals of average 6 years of age using lateral cephalograms. He found that the hyoid bone followed the posteroinferior direction of mandibular rotation during the course of treatment. He concluded his result to be attributed to the tongue repositioning and the proximity of the oropharyngeal and laryngeal spaces to the hyoid bone.

Bibby and Preston[10] (1981), described the hyoid triangle analysis. After an extensive study of the literature, he concluded that the vast variation found in the previous studies may be because of the fact that the hyoid bone was correlated to cranial structures. The hyoid, by virtue of being totally suspended by soft tissues and located away from the cranial structures, any small variation in the position of the reference planes due to head position changes would result in a much greater apparent variation of the hyoid bone.

In their analysis, they related the hyoid bone to the vertebrae and the mandible. Since the mandibular symphysis is at a level more comparable to the axis of rotation of the head than the cranium, the effect of head movement was minimized and the hyoid position was determined more accurately. He had given standard values for the hyoid triangle and also concluded that there is no sexual dimorphism in the position of the hyoid.

Ioannis P.Adamidis et al[38] (1983) evaluated the position of the tongue, mandible and hyoid bone in children aged 9 years having lymphadenoid hypertrophy, mouth breathing and Class I malocclusion. They concluded that the tongue was placed more downwards and forwards in the lymphadenoid hypertrophy group. The mandible showed a clockwise rotation and a significant downward inclination, increased lower anterior facial height and increased gonial angle in lymphadenoid hypertrophy group. The hyoid bone was found to follow the mandibular inclination and was found to rotate and attain a more inferior direction in the lymphadenoid hypertrophy group.

Bibby[11] (1984) used his hyoid triangle analysis to evaluate the hyoid bone position in mouth breathers and tongue thrusters and compared to a control sample. The results did not show any significant differences in hyoid bone position in the three groups compared and he concluded that the hyoid has a stable position independent or any posture alterations due to tongue thrusting or mouth breathing.

McNamara[41] (1984) suggested that lower pharyngeal width can be measured from the intersection of posterior border of tongue and inferior border of the mandible to the closest point on the posterior pharyngeal wall. He felt that the width of the lower pharynx greater than 15 mm suggested anterior positioning of the tongue.

Athanasiou et al[8] (1991) studied the changes in pharyngeal depth and hyoid bone at the level of 2nd and 4th cervical vertebrae and their relationship in mandibular prognathism in lateral cephalograms of patients who received combined orthodontic-surgical treatment. The hypothesis that posterior mandibular repositioning may reduce the airway at the levels of 2nd and 4thcervical vertebrae cannot be supported by the findings of this study. It also indicated that reflex alteration in pharyngeal musculature and biomechanical conditions of supra and infrahyoid muscles occur postoperatively.

Taylor et al[59] (1996) gave brilliant literature regarding the soft tissue growth of oropharynx. With the help of lateral cephalograms, they demonstrated that hyoid bone descends and moves slightly anterior upto age 18. The soft palate increased 1 mm in length and 0.5 mm in thickness every 3years after age 9. Thus, in general, two periods of accelerated change (6-9 yrs. and 12-15 yrs.) and two periods of quiescence (9-12 yrs. and 15-18 yrs.) were identified for pharyngeal soft tissue.

Ioannis Kollias et al[39] (1999) conducted a longitudinal study to investigate by cephalometric means the alterations in craniofacial morphology and hyoid bone positions in males and females in three different age groups with a ten year interval. They concluded that the hyoid bone assumed a more inferior position in adult life in relation to various skeletal structures in both men and women. In males, the descent was more pronounced than that in females. The horizontal position was however found to be stable.

Joanna M. battagel et al[43] (2000) analyzed the upright lateral cephalometric radiographs of 115 dentate Caucasian males. 45 subjects exhibiting proven Obstructive Sleep Apnoea Syndrome, 45 simple snorers and remaining 24 subjects with no history of respiratory disease or snoring, acted as controls. Only the cranial base angle and mandibular body showed significant intergroup differences. Both snorers and OSAS patients exhibited narrow airway, reduced oropharyngeal areas, shorter and thicker soft palate and large tongue than their control counterparts.

Boon H.Seto et al[12] (2001) tested the hypothesis that maxillary morphology differs between OSAS patients and non-snoring, non-apnoea control subjects. Patients had a smaller maxillary to mandibular and maxillary to facial width ratios. These results suggest that OSA patients have narrower, more tapered and shorter maxillary arches than the controls.

Armando Gale et al[5] (2001) studied the hyoid bone position after surgical mandibular advancement and concluded that with a surgical advancement of the mandible the hyoid bone follows the advancement and moves closer to the body of the mandible. However there are variations in the positions of the hyoid bone and head position that are difficult to predict.

Anette M. C. Fransson et al[3] (2002) in their study of influence of mandibular protruding device on airway passages and dentofacial characteristics in obstructive sleep apnoea and snoring evaluated the influence of a mandibular protruding device (MPD) after 2 years of nocturnal usage on the upper airway and its surrounding structures. They concluded that the nocturnal use of an MPD for 2 years improved the airway passage because of an increase in the pharyngeal area by a mean of 9% in OSA patients and snorers. A mandibular posterior rotation and a proclination of the mandibular incisors were observed but considered modest.

Takahashi.S and Ono.T et al[79] (2002) conducted a study on breathing modes, body positions, and suprahyoid muscle activity. Electromyographic activities of genioglossus and geniohyoid muscles were recorded during both nasal and oral breathing, with the subjects were in the both upright and supine positions. The EMG activities of the genioglossus and geniohyoid muscles were compared during mouth opening, swallowing, mandibular advancement, and tongue protrusion. They concluded that EMG activities from the genioglossus and geniohyoid muscles were differentiated well. Also, it appears that variations in the breathing mode and body position significantly affect the genioglossus activity and not that of the geniohyoid activity.

Lena Zettergren-Wijk et al[50] (2002) evaluated longitudinal effect on facial growth after tonsillectomy in children with obstructive sleep apnoea. They studied 14 children with mean age of 5.7 years. Polysomnographic and lateral cephalometric evaluation Preoperative, 1-year postoperative, and 3-year postoperative revealed normalization of the facial growth after relief of the obstruction (tonsillectomy) occurred mostly during the first postoperative year.

Siddik Malkoc, et al[76] (2005) studied the Reproducibility of airway dimensions and tongue and hyoid positions on lateral cephalograms. Three lateral cephalograms each of 30 patients were obtained in natural head positions at 30-minute intermissions. 12 measurements, including pharyngeal airway dimensions and tongue and hyoid positions, were taken and analysed. They concluded that airway dimension and tongue- and hyoid bone position measurements are highly reproducible on natural-head-position cephalograms.

Mirja Kirjavainena & Turkka Kirjavainen[61] (2007) studied the upper airway dimensions in Class II malocclusion and effect of cervical headgear treatment on it using lateral cephalograms. They concluded that Class II division 1 malocclusion is associated with narrower upper airway even without retrognathia. Headgear treatment is associated with an increase in retropalatal airway space.

Craig Fairburn et al[18] (2007) analysed the morphologic 3 dimensional changes in the airway in OSA patients using CT scanning following maxillomandibular advancement surgery. It resulted in a significant increase in both anteroposterior and lateral airway dimensions.

Gunduz Arslan et al[31] (2007) evaluated craniofacial and upper airway structures in lateral cephalograms of patients with hypohydrotic ectodermal dysplasia, whose characteristic features are Class III malocclusion with retrusion of maxilla, and deficiency in vertical, transverse and sagittal growth of the jaw. Ectodermal dysplasia patients have smaller pharyngeal and upper airway dimensions, and hyoid bone is positioned more posteriorly compared with Class III control individuals.

Maria Julia et al[54] (2007) conducted a cephalometric assessment of the hyoid bone position in Oral Breathing Children and concluded that the hyoid bone keeps a stable position, probably in order to secure correct ratios in the airways, and it does not depend on the respiratory pattern.

Yuko Shigeta et al[86] (2008) examined the influence of age and gender on the oropharynx configuration using the computed tomography measurements. They concluded that the airway lengthens with aging specifically in males and speculated that it becomes more collapsible. No significant relationship was identified in females.

Dan Grauer et al[19] (2009) assessed the differences in airway shape and volume among subjects with various facial patterns, using CBCT. Both airway volume and shape vary with different anteroposterior jaw relations; airway shape but not volume differs with various vertical jaw relationships.

Tomonori Iwasaki et al[80] (2009) evaluated the characteristic shape of oropharyngeal airway in children with Class III malocclusion by cone beam computed tomography (CBCT). The Class III malocclusion is associated with a large and flat oropharyngeal airway compared with Class I malocclusion.

Emine Kaygısız et al[23] (2009) appraised the effects of maxillary protraction and fixed appliance therapy on the pharyngeal airway. 25 patients (11 girls, 14 boys;

mean age, 11.32 years) treated with a reverse pull headgear appliance were assessed in their study. They concluded that the nasopharyngeal airway dimensions improved after the treatment with maxillary protraction, and favourable effects in pharyngeal airway remained over the post-treatment period of 4 years.

Soonshin Hwang et al[78] (2010) in their lateral cephalometric study assessed the changes in hyoid, tongue, pharyngeal airway and head posture in patients who had mandibular setback surgery by intraoral vertical ramus osteotomy. The hyoid and tongue moved posteriorly after the setback but had a tendency to relapse back to its original position. However, the final pharyngeal airway width remained narrower even after long term observation period.

Zhe Zhong et al[87] (2010) did a cephalometric 1comparison study of upper airway among different sagittal and vertical facial morphologies in non-snoring children. In normodivergent group, a tendency for reduced upper airway in inferior part was found in Class III, I and Class II subgroups in that order; while in normal sagittal pattern, the superior part of airway decreased with the increasing mandibular plane angle. Thus, they concluded that sagittal and vertical skeletal patterns may be contributory factors for variation in inferior and superior part of upper airway, respectively.

Yoon-Ji Kim et al[83] (2010) studied the three dimensional pharyngeal airway volumes in healthy preadolescent children with different anteroposterior skeletal patterns using CBCT. They compared the airway volume in children with a retrognathic mandible and those with normal craniofacial growth, to study the possible relationship among the studied cephalometric variables and airway morphology. The mean total airway volume in retrognathic patients was significantly smaller than that of normal skeletal relationship. However, the difference in the volume of four sub regions of airway was not statistically significant between the two groups.

Ashok Kumar Jena et al[7] (2010) in their study of sagittal mandibular development effects on the dimensions of the awake pharyngeal airway passage concluded that sagittal mandibular development had significant effects on the dimensions of the awake pharyngeal airway passage. The length of the soft palate was smaller among subjects with mandibular prognathism than among subjects with normal and retrognathic mandibles. The thickness of the soft palate was greater among mandibular prognathic subjects than among subjects with normal and retrognathic mandibles. Sagittal mandibular development had a significant influence on the inclination of the soft palate. The dimensions of the nasopharynx and hypopharynx were independent of sagittal mandibular development. The depth of the oropharynx was greater among subjects with mandibular prognathism than among subjects with normal and retrognathic mandibles

Pirilä-Parkkinen.K et al[66] (2010) in their study about Cephalometric evaluation of children with nocturnal sleep-disordered breathing concluded that upper airway resistance syndrome (UARS) and obstructive sleep apnoea (OSA) were associated with decreased pharyngeal diameters at the levels of the adenoids (PNS–ad1) and tip of the uvula (u1–u2), an increased diameter at the level of the base of the tongue (rl1–rl2), a thicker soft palate, and anteriorly positioned maxilla in relation to the cranial base. Lateral cephalograms may thus reveal important predictors for sleep-disordered breathing (SDB) in children.

Kyung-Min Oh et al[47] (2011) in their study of Three-dimensional analysis of pharyngeal airway form in children with anteroposterior facial patterns concluded that Children with Class II malocclusion have more backward orientation and smaller volume of the pharyngeal airway than do children with Class I and III malocclusion. Inclination of the oropharyngeal airway might be a key factor in determining the form of the entire pharyngeal airway and is related to head posture. In the skeletal Class II group, the average inclination of Oropharyngeal airway was significantly larger and the Oropharyngeal airway in the sagittal plane was shown as a more backward orientation to the FH plane.

Tomonori Iwasaki et al[81] (2011) evaluated the upper airway obstruction in dolichofacial and brachyfacial children with Class II malocclusion. The size of the airway did not differ much between the two facial types. They developed a fluid-mechanical stimulation system to detect the differences in airway obstruction that were not apparent from other morphologic studies.

Gundega Jakobsone et al[30] (2011) evaluated the effect of maxillary advancement and impaction on the upper airway after bimaxillary surgery to correct Class III malocclusion. They concluded that clinically significant advancement (>2 mm) of the maxilla significantly increased the airway dimension at the nasopharyngeal level and to some extent compensated for the effect of mandibular setback at the hypopharyngeal level.

Derya Germec-Cakan et al[22] (2011) compared the changes in Uvulo-glossopharyngeal dimensions in non-extraction, extraction with minimum anchorage and extraction with maximum anchorage. They concluded that superior and middle airway size increased in subjects treated with extraction and minimum anchorage. In patients treated non-extraction by air-rotor stripping, no significant change was observed in airway dimensions. Middle and inferior airway size narrowed in subjects treated with extraction and maximum anchorage.

Pirila-Parkkinen et al[67] (2011) evaluated the validity of upper airway assessment by comparing the capability of two-dimensional lateral cephalograms in recognizing pharyngeal obstruction with that of the three-dimensional magnetic resonance imaging and clinical observation of tonsillar size. The findings confirmed that lateral cephalograms are a valid method for measuring dimensions of nasopharyngeal and retropalatal region; and for evaluating oropharyngeal size, clinical assessment of tonsillar size is a relatively reliable method.

Hakan El and Palomo[32] (2011) evaluated the nasal passage and oropharyngeal airway volumes of patients with different dentofacial skeletal patterns. The study sample consisted of 140 patients which were divided into 3 groups according to the ANB angle as Class I ($1^{\circ} \leq$ ANB $\leq 3^{\circ}$), Class II (ANB $> 3^{\circ}$) and Class III (ANB $< 1^{\circ}$). The area of most constricted region at the base of the tongue had a high potential of explaining the oropharyngeal airway volume; which was smaller for Class II subjects when compared to Class I and Class III subjects. Mandibular position with respect to cranial base had an effect on oropharyngeal airway volume; but the only significant difference in nasopharyngeal volume was between Class I and Class II groups, with a smaller volume observed in Class II group.

Faruk Izzet Ucar and Tancan Uysal[24] (2011) measured the oropharyngeal airway dimensions in subjects with Class I malocclusion and different growth patterns. 31 low angle, 40 high angle and 33 normal growth pattern cases with Class I malocclusion were examined using lateral cephalometric radiographs. Statistically significant differences were found in nasopharyngeal airway space, palatal tongue space, and upper posterior airway space and tongue gap. No significant orofacial airway differences were determined between low angle and normal growth subjects. High angle subjects had larger tongue gap than those with normal and low angle. Nasopharyngeal airway space and upper pharyngeal airway space were larger and palatal tongue space was narrower in low angle than high angle subjects.

Yoshihiko Takemoto et al[84] (2011) evaluated the Pharyngeal airway in children with prognathism and normal occlusion. 25 girls with prognathism and 15 girls with normal occlusion were assessed in their study. They concluded that girls with prognathic mandible had a significantly wider lower pharyngeal airway compared with those with normal occlusion.

Austin Phoenix et al[9] (2011) studied the changes in hyoid bone position following rapid maxillary expansion in adolescents and noted that before treatment, the hyoid to mandibular plane distance is greater in patients with narrow maxillae requiring RME. They concluded that the hyoid to mandibular plane distance significantly decreased post rapid maxillary expansion while the tongue length remained unaffected. They suggested that RME treatment tends to normalize hyoid bone position.

Ashok Kumar and Ritu Duggal[6] (2011) studied the hyoid bone position in subjects with different vertical jaw dysplasia and concluded that the anteroposterior position of the hyoid bone was more forward in subjects with short face syndrome. The vertical position of the hyoid bone was comparable among subjects with different vertical jaw dysplasias. The axial inclination of the hyoid bone closely followed the axial inclination of the mandible.

Qingzhu Wang, Peizeng Jia, Nina K. Anderson, Lin Wang and Jiuxiang Lin[70] (2012) in their study compared the Changes of pharyngeal airway size and hyoid bone position following orthodontic treatment of Class I bimaxillary protrusion concluded that following retraction of incisors, the velopharyngeal, glossopharyngeal, and hypopharyngeal airway became narrower. The changes of the pharyngeal airway size were no different between the hyperdivergent and non-hyperdivergent groups. The hyoid bone tends to move in a posterior and inferior direction. A significant relationship has been demonstrated between the reduction of the velopharynx, glossopharynx, and the retraction distance of lower incisors in their study.

Fitin Aloufi et al[25] (2012) in their retrospective study about the changes in the upper and lower pharyngeal airway spaces associated with rapid maxillary expansion concluded that rapid maxillary expansion during orthodontic treatment have a positive effect on the upper nasopharyngeal airway, with no significant change on the lower pharyngeal airway. They also confirmed that there was no significant difference with respect to mode of breathing.

Nanda Kishore Sahoo et al[63] (2012) evaluated the upper airway dimensional changes and hyoid position following mandibular advancement in patients with skeletal Class II malocclusion. They quantified upper airway dimensional changes and hyoid bone positional variation for a given degree of mandibular advancement. They established a ratio of mandibular advancement to increase in airway dimensions. The mean ratio of mandibular advancement to increase Posterior Airway Space, Superior Airway Space, and Minimum Airway Space was 1:0.35, 1:0.34, and 1:0.24, respectively. Hyoid bone moved superiorly and in an anterior direction by 2.1 ± 2.8 mm.

Yu Chen et al[85] (2012) evaluated the effect of large incisor retraction on upper airway morphology in adult bimaxillary protrusion patients using three-dimensional multi slice computed tomography. 30 adult patients with bimaxillary protrusion treated with four first premolars extractions and miniscrews anchorage were evaluated. They concluded that the hyoid was retracted in the horizontal and vertical directions. No significant difference was observed in the cross-sectional area of the nasopharynx, while significant differences were found in the mean cross-sectional areas of the glossopharynx, palatopharynx and hypopharynx these mean cross-sectional areas were decreased. The largest change in the cross-sectional area is always noted in the hypopharynx.

Sila Mermut Gokce et al[77] (2012) studied the relationship between Class III malocclusion and hyoid bone displacement during swallowing by using cinemagnetic resonance imaging and concluded that the forward and upward displacements of the hyoid bone during bolus swallowing were significantly related to craniofacial morphology. Although the pattern of hyoid bone movement during swallowing was similar in patients with skeletal Class III malocclusion and control subjects with normal occlusion, differences were noted in the degree of the movement. Specifically, as the magnitude of the skeletal Class III deformity increased, the amount of forward and upward displacement of the Hyoid bone increased.

Halise Aydemir et al[33] (2012) in their study of Pharyngeal airway space, hyoid bone position and head posture after orthognathic surgery in Class III patients concluded that different surgical procedures have different effects on pharyngeal airway space. Mandibular setback surgeries cause the most narrowing effect on the pharyngeal airway. Bimaxillary surgeries mostly decrease the narrowing effect of the mandibular setback surgeries and must be preferred when planning these cases. Maxillary advancement procedures have a widening effect on the pharyngeal airway. No significant change occurs in craniocervical posture and hyoid bone position after Class III orthognathic surgeries.

Materials and methods

In this study, the treatment records of 40 patients who underwent fixed orthodontic treatment between the years 2006 to 2009 at Department Of Orthodontics and Dentofacial Orthopaedics, Tamilnadu Government Dental College and Hospital Chennai were analysed. Of 40 sets of standardized lateral cephalometric radiographs 20 were Class I malocclusion and 20 were Class II malocclusion. The control group consisting of 20 lateral cephalograms of subjects with normal occlusion and good visibility of hyoid bone were used. The age range was between 18 and 25 years. Inclusion and exclusion criteria were analysed from the clinical records of the subjects.

Selection criteria:

The lateral cephalograms evaluated for this study were taken in natural head position, with PLANMECA PM 2002 CC PROLINE machine 70kvp, 30mA, for 1.8seconds from fixed distance of 60 inches from the cephalostat available in the Department Of Oral Medicine and Radiology, Tamilnadu Government Dental College and Hospital Chennai. All cephalograms were taken in same cephalostat with Frankfort horizontal plane of the subjects parallel to the floor. All cephalograms were standardized using a transparent grid of 1mm accuracy and Adobe Photoshop CS5. All the radiographs were scanned with CANON D520 MF scanner and digitized. A Cephalometric analysis software **AX CEPH** version 2.3.0.74 was used to analyse the radiographs.

Inclusion criteria for Class I group:

- Skeletal Class I (ANB 2º- 4º), Class I molar and canine relationship.
- Both maxillary and mandibular arches with moderate to severe crowding [69] (4-10 mm - moderate to severe crowding according to Little's irregularity index)
- Orthodontic treatment with extraction of four first premolars.
- Average BMI and Growth pattern.
- No obvious hyperplasia of tonsils or adenoids on cephalograms.
- Pretreatment and posttreatment radiographs with good soft and hard tissue outlines with good visibility of the hyoid bone and teeth in full occlusion, lips resting in natural position.

Inclusion criteria for Class II group:

- Mild to moderate skeletal Class II (ANB 5º-7º), Class II molar and canine relationship.
- Both maxillary and mandibular arches with moderate to severe crowding [69] (4-10 mm – moderate to severe crowding according to Little's irregularity index)
- Orthodontic treatment with extraction of two first premolars in upper arch & two second premolars in lower arch.
- Average BMI and Growth pattern.
- No obvious hyperplasia of tonsils or adenoids and tongue on cephalograms.

- Pretreatment and posttreatment cephalograms with good soft and hard tissue with good visibility of the hyoid bone outlines and teeth in full occlusion, lips resting in natural position.

Exclusion criteria:

- Craniofacial anomalies.
- History of craniofacial trauma & pathology.
- History of previous craniofacial surgery / orthodontic treatment.
- History of abnormal oral habits.
- History of nasal obstruction and allergic conditions.

Cephalometric evaluation:

The pharynx is divided into of four different sections, nasopharynx, velopharynx, glossopharynx, and hypopharynx. 7 parameters for these 4 sections of pharynx and 4 parameters for hyoid bone positions were selected and analysed [70] .

<u>Cephalometric Landmarks and Measurements Analysed :</u>

<u>Table 1 : Cephalometric landmarks</u>

Hor	Most inferior point of spheno-occipital synchondrosis
R	Point of intersection of line from Hor to PNS and posterior pharyngeal wall
Ba	Lowermost point on anterior margin of foramen magnum
Ad1	Point of intersection of posterior pharyngeal wall and line Ptm-Ba

SPPW	Point of intersection of line from soft palate center perpendicular to posterior pharyngeal wall and posterior pharyngeal wall
SPP	Point of intersection of line from soft palate center perpendicular to posterior pharyngeal wall and posterior margin of soft palate
U	The tip of the uvula
MPW	Foot point of perpendicular line from point U to posterior pharyngeal wall
TPPW	Point of intersection of posterior pharyngeal wall and extension of line B-Go
V	The most posteroinferior point on the base of the tongue
TB	Point of intersection of base of the tongue & extension of line B-Go
LPW	Foot point of perpendicular line from point V to posterior pharyngeal wall
E	Base of epiglottis.
C3	The most anteroinferior point of the third vertebra
H	The most superior and anterior point of hyoid bone
RGN	The most protrusive point of retrognathion
H1	Foot point of perpendicular line from RGN to C3

Table 2 :Airway Parameters (in mm)

VAL	Vertical airway length, distance between PNS and V
PNS-R	Distance between PNS and R.
PNS-Ad1	Distance between PNS and Ad1.
SPP-SPPW	Distance between SPP and SPPW.
U-MPW	Distance between U and MPW.
TB-TPPW	Distance between TB and TPPW.
U-MPW	Distance between U and MPW.
TB-TPPW	Distance between TB and TPPW.
V-LPW	Distance between V and LPW.

Table 3: Hyoid Position Parameters (in mm)

HRgn , mm	Distance between H and RGN
HH1, mm	Distance between H and H1
C3H, mm	Distance between C3 and H
SH, mm	Distance between S and H

Table 4 :Dentofacial Parameters

ANB, degrees	Angle between point A and B at nasion
FH-MP, degrees	Angle between the mandibular plane and the FH plane
U1-FH, degrees	Angle between the FH plane & long axis of upper incisors
L1-MP, degrees	Angle between the mandibular plane and long axis of lower

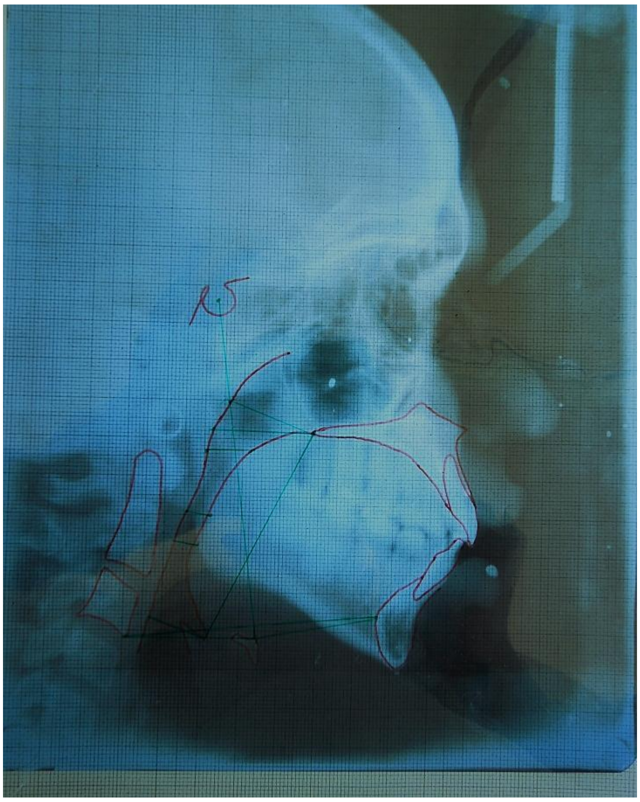
	incisors
UL-E line, mm	Horizontal distance from the most protrusive point of upper lip to E line
LL-E line, mm	Horizontal distance from the most protrusive point of lower lip to E line
U1FHp, mm	Horizontal distance from the tip of the upper incisor crown to constructed FH plane vertical
L1FHp, mm	Horizontal distance from the tip of the lower incisor crown to constructed FH plane vertical
U6FHp, mm	Horizontal distance from the distal point of the upper first molar crown to constructed FH plane vertical
L6FHp, mm	Horizontal distance from the distal point of the lower first molar crown to constructed FH plane vertical

The process of digitization, landmark identification and analysis for all cephalograms were carried out by same investigator. The intra-examiner reliability was evaluated by re-recording the measurements at three weeks interval.

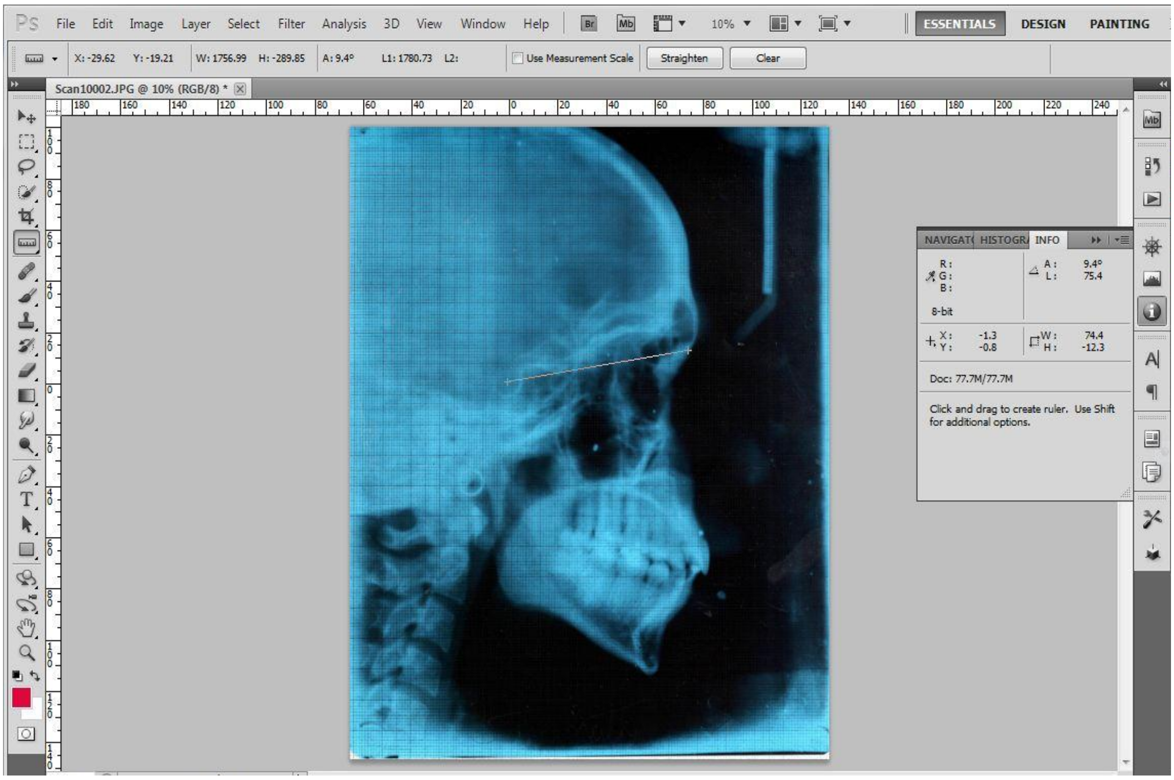
Cephalostat

CANON D520 MF scanner

Standardization with Transparent Grid

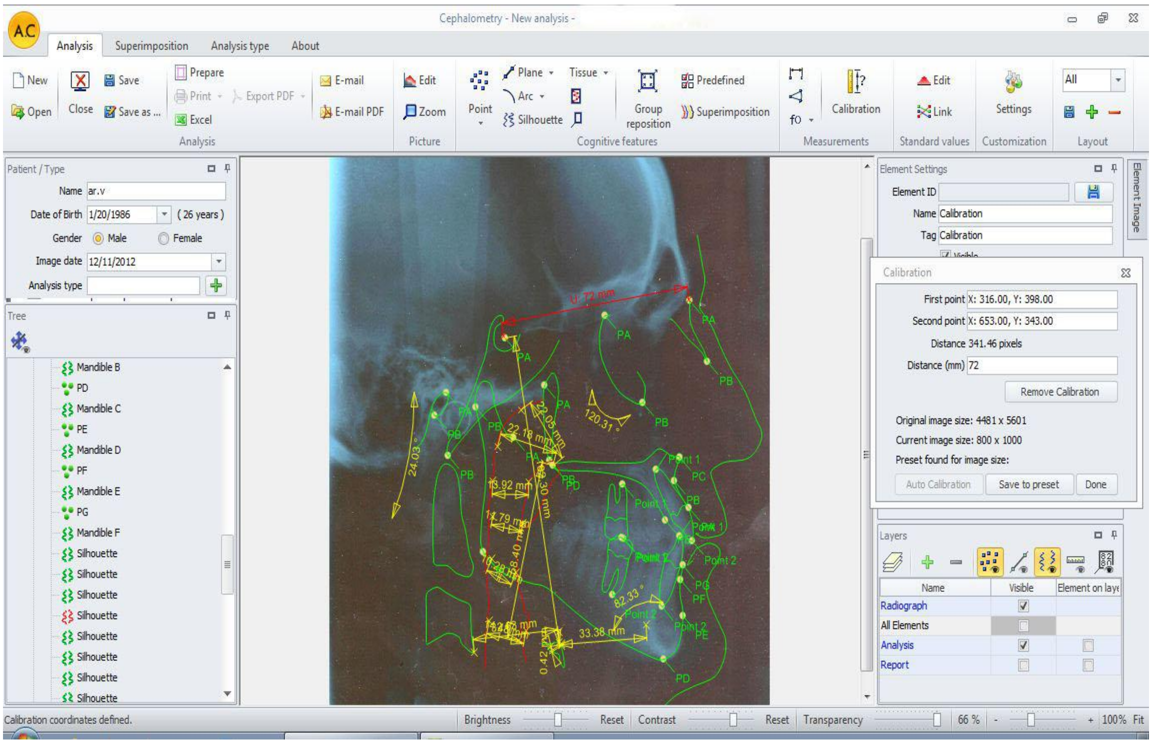


Standardization with Adobe Photoshop CS5

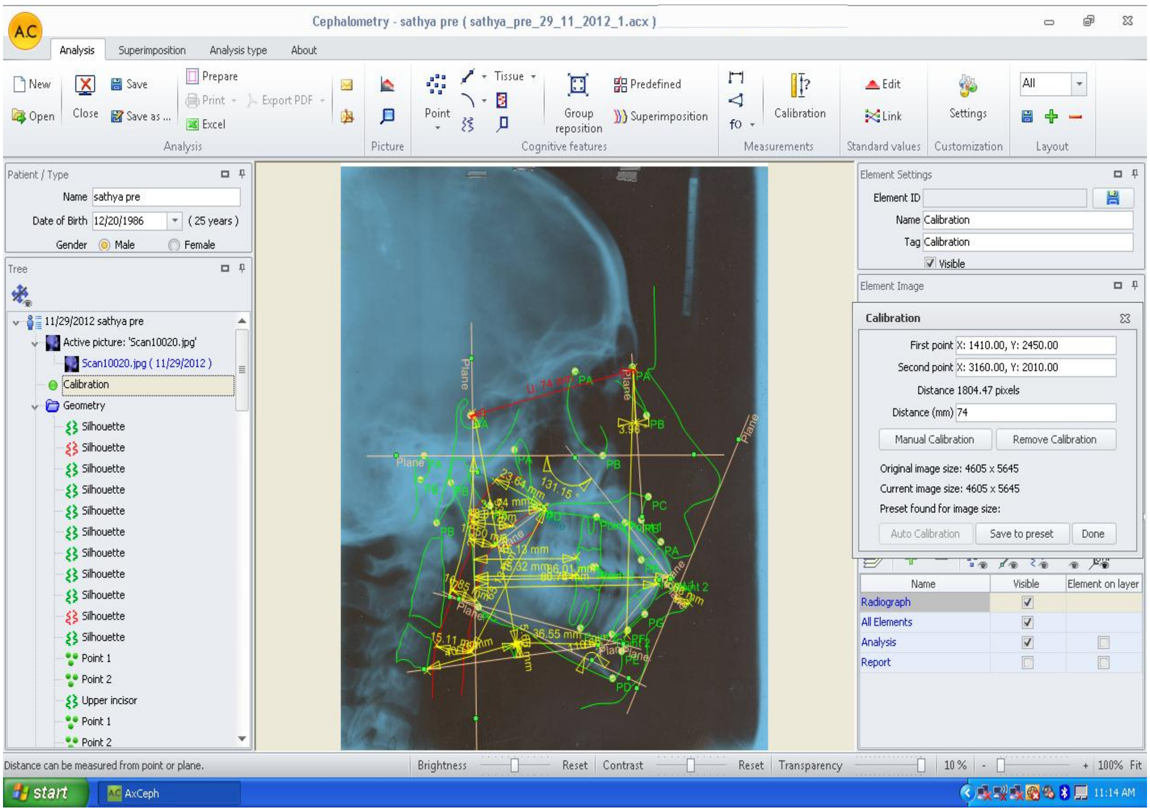


Ax Ceph Cephalometric Analysis Software

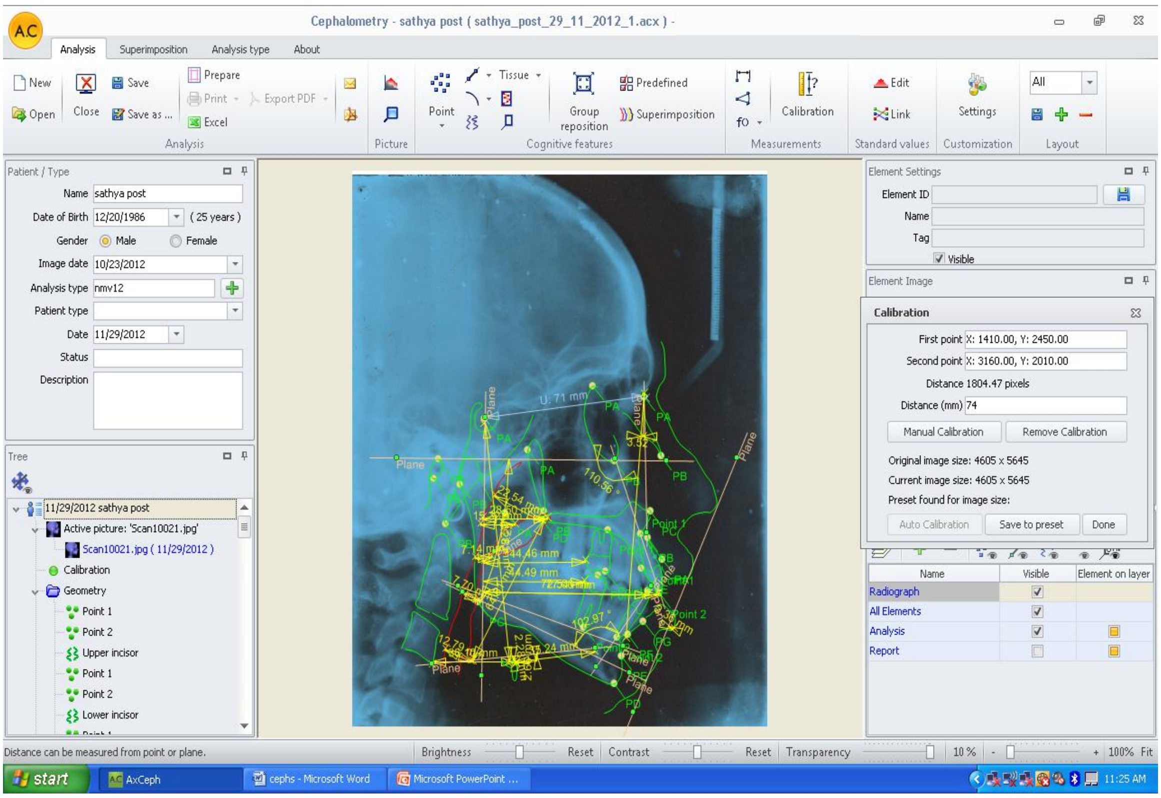
Analysis of digitized lateral cephalograms – Control subject



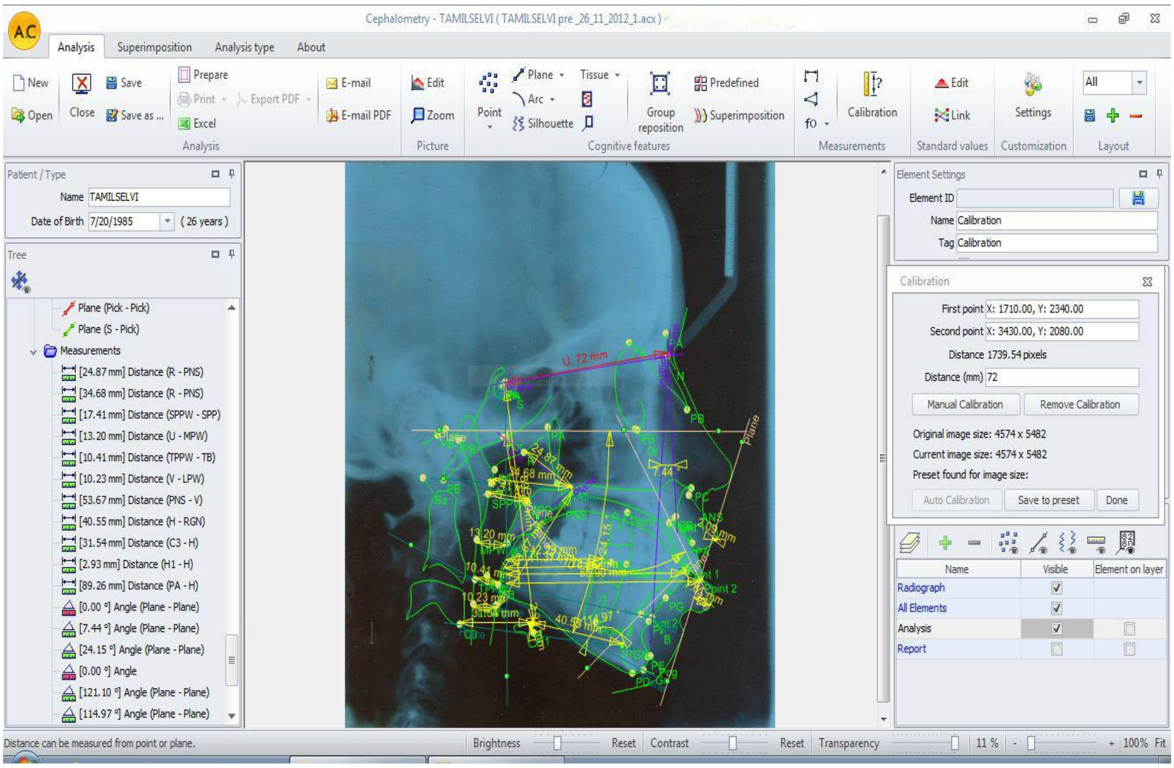
Analysis of digitized lateral cephalograms of Class I subject - pretreatment



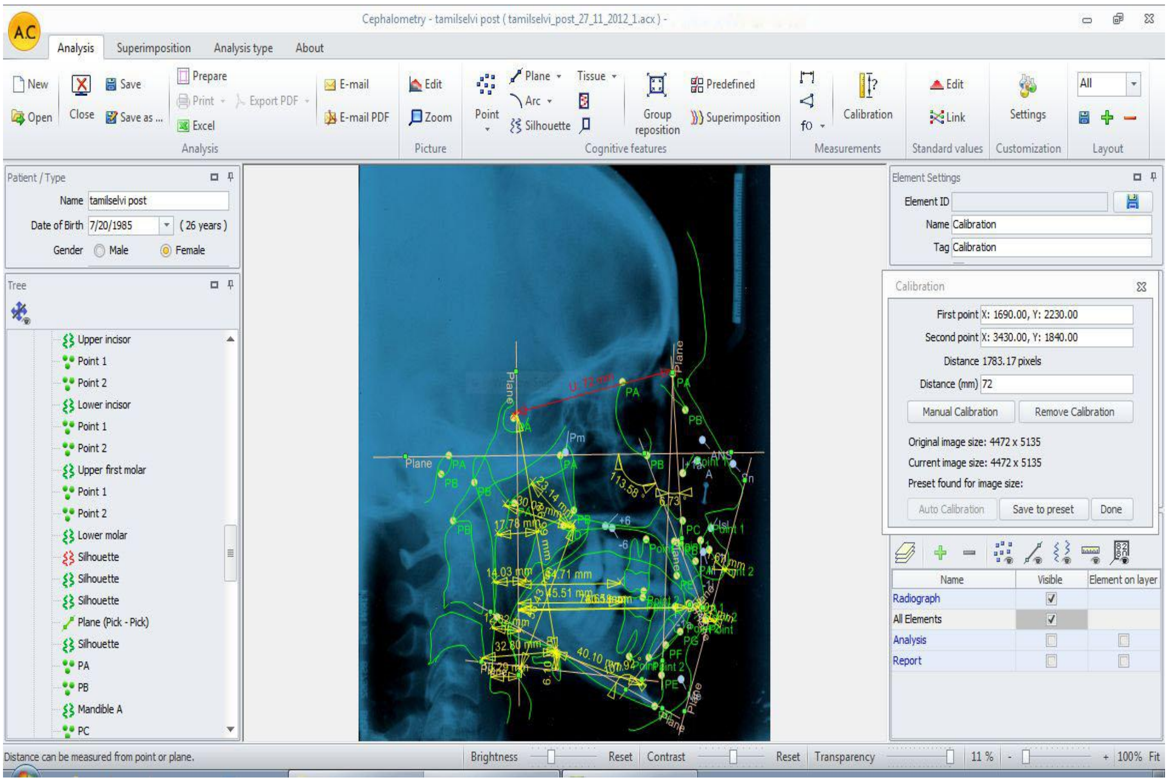
Analysis of digitized lateral cephalograms of Class I subject - posttreatment



Analysis of digitized lateral cephalograms of Class II subject - pretreatment



Analysis of digitized lateral cephalograms of Class II subject - posttreatment



Statistical Analysis

The data collected during the study was recorded in Microsoft Excel Spreadsheet. The data was subjected to data analysis using Statistical Package for Social Sciences (SPSS) software version 17. Within group differences in data pertaining to airway dimension parameters, hyoid bone position parameters and Dentofacial parameters among Class I and Class II malocclusion group before and after treatment was compared using paired t test. Between group differences in the above parameters among subjects with ideal group, Class I group and Class II group was compared using one way ANOVA.

The intra-examiner reliability in recording the measurements was assessed using Cronbach's alpha method.

For all the analysis, p value of < 0.05 was considered to be statistically significant.

RESULTS

Table 5: Distribution of study subjects based on their gender

Gender	Normoocclusion (n)	Class I group (n)	Class II group (n)
Male	10	9	12
Female	10	11	8
Chi square value – 0.93	**df – 2**		**p value - 0.62 (NS)**

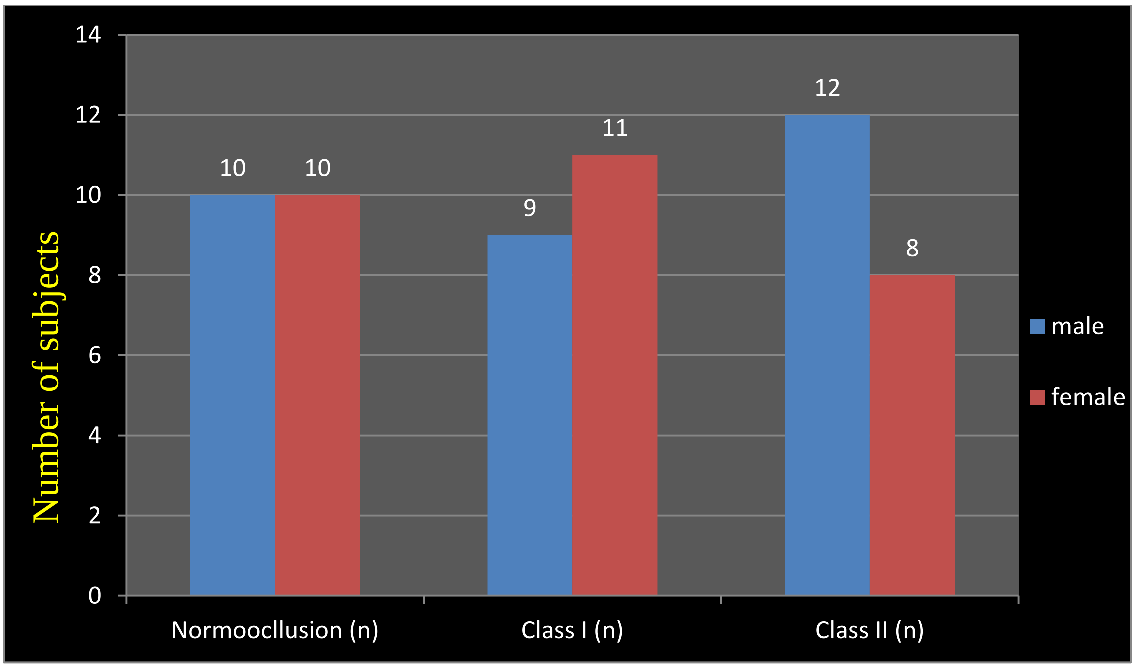
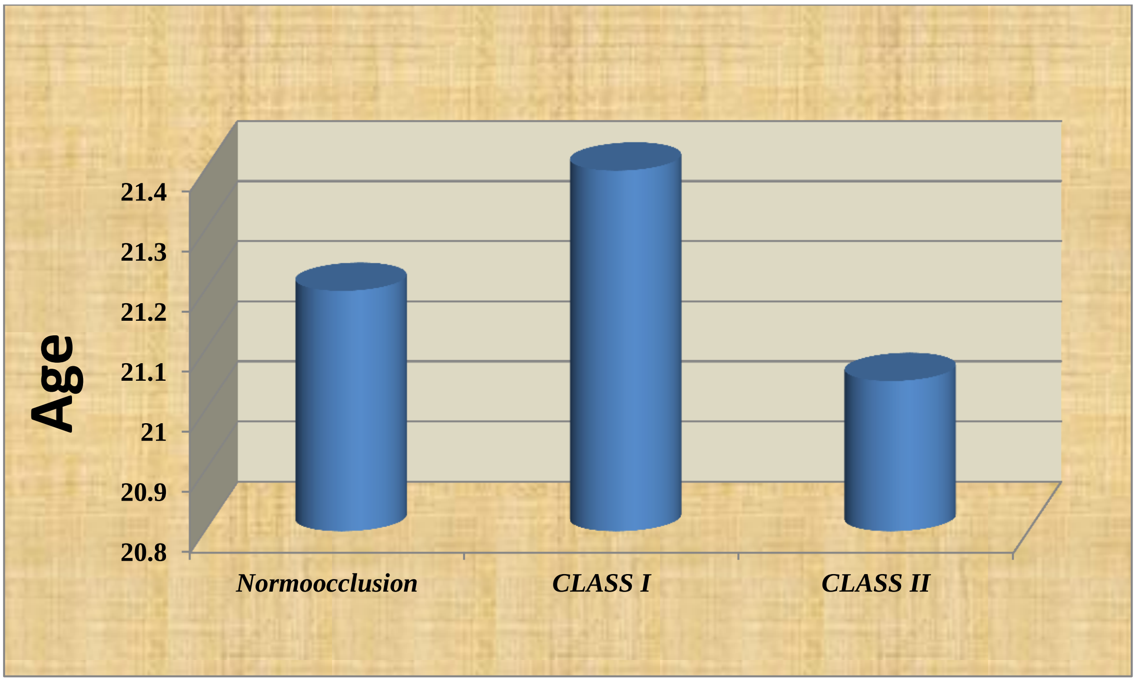


Table 6: Distribution of study subjects based on their age

Type of occlusion	Mean age	S.D	F value	p value
Normoocclusion	21.2	1.92	2.74	0.07 (NS)
Class I group	21.4	1.81		
Class II group	21.05	1.76		



The intra-examiner reliability was evaluated by re-recording the measurements at three weeks interval. The kappa value for reliability was found to be 0.84 denoting a high level of consistency in recording the measurements at two different time period.

Table 7: Comparison of Airway related parameters among study subjects within Class I malocclusion group

Variable		Mean	Std. Devn	Mean difference	t value	df	p value
PNS –R (mm)	**Pre-treatment**	**22.36**	**1.66**	**-0.20**	**-3.27**	**19**	**0.004**
	Post-treatment	**22.55**	**1.65**				
PNS -Ad1 (mm)	**Pre-treatment**	**31.45**	**1.21**	**0.26**	**3.69**	**19**	**0.002**
	Post-treatment	**31.20**	**1.33**				
SPP-SPPW (mm)	**Pre-treatment**	**17.95**	**1.00**	**0.36**	**4.07**	**19**	**0.001**
	Post-treatment	**17.58**	**1.10**				
U-MPW (mm)	**Pre-treatment**	**11.39**	**0.97**	**0.60**	**3.33**	**19**	**0.004**
	Post-treatment	**10.79**	**1.21**				
TB-TPPW (mm)	**Pre-treatment**	**10.85**	**0.95**	**0.73**	**5.91**	**19**	**0.001**
	Post-treatment	**10.12**	**0.95**				
V-LPW (mm)	**Pre-treatment**	**14.08**	**1.37**	**1.14**	**14.44**	**19**	**0.001**
	Post-treatment	**12.93**	**1.41**				
VAL (mm)	**Pre-treatment**	**60.72**	**1.39**	**-0.95**	**-6.42**	**19**	**0.001**
	Post-treatment	**61.67**	**1.35**				

Table 8: Comparison of Hyoid position related parameters among study subjects within Class I malocclusion group

Variable		Mean	Std. Devn	Mean difference	t value	df	p value
HRGN (mm)	**Pre-treatment**	**34.30**	**1.27**	**-1.04**	**-6.46**	**19**	**0.001**
	Post-treatment	**35.34**	**1.31**				
HH1 (mm)	**Pre-treatment**	**3.58**	**0.81**	**-0.38**	**-2.28**	**19**	**0.035**
	Post-treatment	**3.95**	**0.69**				
C3H (mm)	**Pre-treatment**	**38.18**	**1.25**	**0.89**	**7.68**	**19**	**0.001**
	Post-treatment	**37.29**	**1.16**				
SH (mm)	**Pre-treatment**	**91.74**	**3.13**	**-1.30**	**-9.40**	**19**	**0.001**
	Post-treatment	**93.04**	**2.89**				

Table 9: Comparison of Dento-facial related parameters among study subjects within Class I malocclusion group

Variable		Mean	Std. Deviation	Mean difference	t value	df	p value
ANB (degree)	**Pre-treatment**	**3.11**	**0.71**	**-0.11**	**-1.67**	**19**	**0.112**
	Post-treatment	**3.22**	**0.64**				
FH-MP (degree)	**Pre-treatment**	**25.27**	**2.11**	**-0.37**	**-4.72**	**19**	**0.001**
	Post-treatment	**25.63**	**2.15**				
U1-FH (degree)	**Pre-treatment**	**128.64**	**4.41**	**14.92**	**38.16**	**19**	**0.001**
	Post-treatment	**113.73**	**3.64**				
L1-MP (degree)	**Pre-treatment**	**100.50**	**4.30**	**6.51**	**21.77**	**19**	**0.001**
	Post-treatment	**94.00**	**3.46**				
UL-Eline (mm)	**Pre-treatment**	**3.23**	**1.18**	**2.13**	**11.37**	**19**	**0.001**
	Post-treatment	**1.10**	**0.47**				
LL-Eline (mm)	**Pre-treatment**	**5.28**	**0.84**	**3.24**	**22.19**	**19**	**0.001**
	Post-treatment	**2.04**	**0.53**				
U1-FHP (mm)	**Pre-treatment**	**79.19**	**2.62**	**6.26**	**25.76**	**19**	**0.001**
	Post-treatment	**72.93**	**2.69**				
L1-FHP (mm)	**Pre-treatment**	**75.27**	**2.28**	**4.70**	**24.47**	**19**	**0.001**
	Post-treatment	**70.57**	**2.31**				
U6-FHP (mm)	**Pre-treatment**	**40.11**	**1.40**	**-0.60**	**-7.78**	**19**	**0.001**
	Post-treatment	**40.71**	**1.53**				
L6-FHP (mm)	**Pre-treatment**	**40.55**	**1.40**	**-0.62**	**-8.57**	**19**	**0.001**
	Post-treatment	**41.17**	**1.62**				

Table 10: Comparison of Airway related parameters among study subjects within Class II malocclusion group

Variable		Mean	Std. Devn	Mean difference	t value	df	p value
PNS –R (mm)	**Pre-treatment**	**25.45**	**1.34**	**.46**	**3.63**	**19**	**.002**
	Post-treatment	**24.99**	**1.38**				
PNS -Ad1 (mm)	**Pre-treatment**	**34.55**	**1.36**	**.78**	**3.47**	**19**	**.003**
	Post-treatment	**33.78**	**1.83**				
SPP-SPPW (mm)	**Pre-treatment**	**16.48**	**1.24**	**-.09**	**-.73**	**19**	**.476**
	Post-treatment	**16.57**	**1.16**				
U-MPW (mm)	**Pre-treatment**	**13.85**	**1.04**	**-1.05**	**-12.46**	**19**	**0.001**
	Post-treatment	**14.91**	**1.07**				
TB-TPPW (mm)	**Pre-treatment**	**11.06**	**1.23**	**-1.29**	**-14.23**	**19**	**0.001**
	Post-treatment	**12.35**	**1.06**				
V-LPW (mm)	**Pre-treatment**	**11.03**	**1.32**	**-2.31**	**-21.59**	**19**	**0.001**
	Post-treatment	**13.34**	**1.32**				
VAL (mm)	**Pre-treatment**	**55.95**	**2.20**	**-1.31**	**-8.29**	**19**	**0.001**
	Post-treatment	**57.26**	**2.49**				

Table 11: Comparison of Hyoid position parameters among study subjects within Class II malocclusion group

Variable		Mean	Std. Devn	Mean difference	t value	df	p value
HRGN (mm)	**Pre-treatment**	**36.41**	**2.59**	**.38**	**14.90**	**19**	**0.001**
	Post-treatment	**36.03**	**2.58**				
HH1 (mm)	**Pre-treatment**	**2.73**	**.81**	**.49**	**8.67**	**19**	**0.001**
	Post-treatment	**2.24**	**.79**				
C3H (mm)	**Pre-treatment**	**34.79**	**2.37**	**-.94**	**-10.98**	**19**	**0.001**
	Post-treatment	**35.73**	**2.37**				
SH (mm)	**Pre-treatment**	**93.85**	**3.64**	**1.19**	**6.72**	**19**	**0.001**
	Post-treatment	**92.66**	**3.73**				

Table 12: Comparison of Dento facial related parameters among study subjects within Class II malocclusion group

variable		Mean	Std. Devn	Mean difference	t value	df	p value
ANB (degree)	**Pre-treatment**	**5.98**	**.79**	**.67**	**11.05**	**19**	**0.001**
	Post-treatment	**5.31**	**.67**				
FH-MP (degree)	**Pre-treatment**	**26.03**	**1.59**	**-.75**	**-8.20**	**19**	**0.001**
	Post-treatment	**26.78**	**1.60**				
U1-FH (degree)	**Pre-treatment**	**125.93**	**3.78**	**11.72**	**22.21**	**19**	**0.001**
	Post-treatment	**114.21**	**3.32**				
L1-MP (degree)	**Pre-treatment**	**101.78**	**4.78**	**7.45**	**13.29**	**19**	**0.001**
	Post-treatment	**94.33**	**3.53**				
UL-Eline (mm)	**Pre-treatment**	**4.41**	**1.06**	**2.66**	**12.83**	**19**	**0.001**
	Post-treatment	**1.75**	**.29**				
LL-Eline (mm)	**Pre-treatment**	**5.36**	**.81**	**3.34**	**27.10**	**19**	**0.001**
	Post-treatment	**2.02**	**.32**				
U1-FHP (mm)	**Pre-treatment**	**87.72**	**2.28**	**5.25**	**29.13**	**19**	**0.001**
	Post-treatment	**82.47**	**1.86**				
L1-FHP (mm)	**Pre-treatment**	**83.64**	**2.09**	**3.09**	**21.21**	**19**	**0.001**
	Post-treatment	**80.56**	**2.21**				
U6-FHP (mm)	**Pre-treatment**	**40.38**	**1.14**	**-.64**	**-5.61**	**19**	**0.001**
	Post-treatment	**41.02**	**1.36**				
L6-FHP (mm)	**Pre-treatment**	**38.76**	**1.18**	**-3.23**	**-14.13**	**19**	**0.001**
	Post-treatment	**41.99**	**1.21**				

TABLE 13: Comparison of airway parameters between Class I and Class II malocclusion groups

	Class	N	Mean	Std. Devn	Std. Error Mean
PNS-R PRE	Class 1	20	22.3560	1.66376	.37203
	Class 2	20	25.4455	1.33739	.29905
PNS-R POST	Class 1	20	22.554	1.6472	.3683
	Class 2	20	24.987	1.3848	.3096
PNS-AD1 PRE	Class 1	20	31.4545	1.21288	.27121
	Class 2	20	34.5525	1.36179	.30451
PNS-AD1 POST	Class 1	20	31.198	1.3254	.2964
	Class 2	20	33.775	1.8265	.4084
SPP-SPPW PRE	Class 1	20	17.9450	1.00384	.22447
	Class 2	20	16.4785	1.23577	.27633
SPP-SPPW POST	Class 1	20	17.5810	1.09900	.24574
	Class 2	20	16.5680	1.15832	.25901
U-MPW PRE	Class 1	20	11.3905	.96696	.21622
	Class 2	20	13.8520	1.04164	.23292
U-MPW POST	Class 1	20	10.7900	1.21063	.27071
	Class 2	20	14.9055	1.06762	.23873
TB – TPPW PRE	Class 1	20	10.8480	.95446	.21342
	Class 2	20	11.0585	1.22819	.27463
TB – TPPW POST	Class 1	20	10.1220	.95095	.21264
	Class 2	20	12.3500	1.05607	.23614
V-LPW PRE	Class 1	20	14.0780	1.37332	.30708
	Class 2	20	11.0280	1.31877	.29489
V-LPW POST	Class 1	20	12.9340	1.41081	.31547
	Class 2	20	13.3425	1.31865	.29486
VAL PRE	Class 1	20	60.716	1.3861	.3100
	Class 2	20	55.946	2.1985	.4916
VAL POST	Class 1	20	61.666	1.3455	.3009
	Class 2	20	57.257	2.4904	.5559

Table 14: Comparison of Airway Parameters between Class I And Class II Malocclusion Groups - Independent Samples Test

		Levene's test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
PNS-R PRE	Equal variances assumed	.927	.342	-6.473	38	<.001	-3.0895	.47732
	Equal variances not assumed			-6.473	36.322	<.001	-3.0895	.47732
PNS-R POST	Equal variances assumed	.757	.390	-5.055	38	<.001	-2.432	.4812
	Equal variances not assumed			-5.055	36.910	<.001	-2.432	.4812
PNS-AD1 PRE	Equal variances assumed	.875	.355	-7.597	38	<.001	-3.0980	.40777
	Equal variances not assumed			-7.597	37.502	<.001	-3.0980	.40777
PNS-AD1 POST	Equal variances assumed	3.607	.065	-5.107	38	<.001	-2.577	.5046
	Equal variances not assumed			-5.107	34.666	<.001	-2.577	.5046
SPP-SPPW PRE	Equal variances assumed	.776	.384	4.119	38	<.001	1.4665	.35601
	Equal variances not assumed			4.119	36.469	<.001	1.4665	.35601
SPP-SPPW POST	Equal variances assumed	.007	.936	2.837	38	.007	1.0130	.35704
	Equal variances not assumed			2.837	37.895	.007	1.0130	.35704
U-MPW PRE	Equal variances assumed	.223	.640	-7.745	38	<.001	-2.4615	.31781
	Equal variances not assumed			-7.745	37.792	<.001	-2.4615	.31781

U-MPW POST	Equal variances assumed	.001	.982	-11.402	38	<.001	-4.1155	.36093
	Equal variances not assumed			-11.402	37.415	<.001	-4.1155	.36093
TB – TPPW PRE	Equal variances assumed	1.350	.253	-.605	38	.549	-.2105	.34781
	Equal variances not assumed			-.605	35.816	.549	-.2105	.34781
TB – TPPW POST	Equal variances assumed	1.214	.277	-7.011	38	<.001	-2.2280	.31777
	Equal variances not assumed			-7.011	37.590	<.001	-2.2280	.31777
V-LPW PRE	Equal variances assumed	.053	.820	7.164	38	<.001	3.0500	.42574
	Equal variances not assumed			7.164	37.938	<.001	3.0500	.42574
V-LPW POST	Equal variances assumed	.271	.605	-.946	38	.350	-.4085	.43181
	Equal variances not assumed			-.946	37.828	.350	-.4085	.43181
VAL PRE	Equal variances assumed	5.365	.026	8.206	38	<.001	4.769	.5812
	Equal variances not assumed			8.206	32.045	<.001	4.769	.5812
VAL POST	Equal variances assumed	5.890	.020	6.966	38	<.001	4.409	.6329
	Equal variances not assumed			6.966	29.222	<.001	4.409	.6329

Table 15: Comparison of hyoid position related parameters between Class I and Class II malocclusion groups.

	Class	N	Mean	Std. Deviation	Std. Error Mean
H-RGN PRE	Class 1	20	34.2990	1.26646	.28319
	Class 2	20	36.4110	2.59176	.57954
H-RGN POST	Class 1	20	35.3360	1.31194	.29336
	Class 2	20	36.0305	2.58043	.57700
HH1 PRE	Class 1	20	3.5775	.80951	.18101
	Class 2	20	2.7280	.80983	.18108
HH1 POST	Class 1	20	3.9525	.69208	.15475
	Class 2	20	2.2400	.79382	.17750
C3H PRE	Class 1	20	38.1810	1.25319	.28022
	Class 2	20	34.7930	2.36943	.52982
C3H POST	Class 1	20	37.288	1.1603	.2594
	Class 2	20	35.733	2.3734	.5307
SH PRE	Class 1	20	91.7360	3.13418	.70082
	Class 2	20	93.8490	3.64104	.81416
SH POST	Class 1	20	93.037	2.8947	.6473
	Class 2	20	92.664	3.7273	.8335

Table 16: Comparison of hyoid position related parameters between subjects with Class I and Class II occlusion - Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference
H-RGN PRE	Equal variances assumed	14.986	.000	-3.274	38	.002	-2.1120	.64502
	Equal variances not assumed			-3.274	27.584	.003	-2.1120	.64502
H-RGN POST	Equal variances assumed	14.247	.001	-1.073	38	.290	-.6945	.64729
	Equal variances not			-1.073	28.207	.292	-.6945	.64729

	assumed							
HH1 PRE	Equal variances assumed	.014	.908	3.318	38	.002	.8495	.25604
	Equal variances not assumed			3.318	38.000	.002	.8495	.25604
HH1 POST	Equal variances assumed	.357	.553	7.272	38	<.001	1.7125	.23549
	Equal variances not assumed			7.272	37.307	<.001	1.7125	.23549
C3H PRE	Equal variances assumed	8.663	.006	5.653	38	<.001	3.3880	.59936
	Equal variances not assumed			5.653	28.859	<.001	3.3880	.59936
C3H POST	Equal variances assumed	8.561	.006	2.631	38	.012	1.555	.5907
	Equal variances not assumed			2.631	27.591	.014	1.555	.5907
SH PRE	Equal variances assumed	.121	.730	-1.967	38	.057	-2.1130	1.07425
	Equal variances not assumed			-1.967	37.177	.057	-2.1130	1.07425
SH POST	Equal variances assumed	1.002	.323	.353	38	.726	.373	1.0553
	Equal variances not assumed			.353	35.806	.726	.373	1.0553

Table 17: Comparison of airway related parameters between subjects with Normal, Class I and Class II occlusion at baseline (mm)

Variable	Normal subjects	Class I subjects	Class II subjects	F value*	p value
PNS –R (mm)	22.6	22.36	25.45	15.17	< 0.001
PNS -Ad1 (mm)	28.61	31.45	34.55	37.11	< 0.001
SPP-SPPW (mm)	15.95	17.95	16.48	3.72	0.03
U-MPW (mm)	10.78	11.39	13.85	34.10	< 0.001
TB-TPPW (mm)	10.34	10.85	11.06	0.85	0.43
V-LPW (mm)	15.11	14.08	11.03	25.5	< 0.001
VAL (mm)	59.54	60.72	55.95	12.91	< 0.001

***One way ANOVA**

Table 18: Comparison of airway related parameters between subjects with Normal, Class I and Class II occlusion post treatment (mm)

Variable	Normal subjects	Class I subjects	Class II subjects	F value*	p value
PNS –R (mm)	22.6	22.55	24.99	9.92	< 0.001
PNS -Ad1 (mm)	28.61	31.2	33.78	24.94	< 0.001
SPP-SPPW (mm)	15.95	17.58	16.57	2.34	0.104
U-MPW (mm)	10.78	10.79	14.91	65.02	< 0.001
TB-TPPW (mm)	10.34	10.12	12.35	9.78	< 0.001
V-LPW (mm)	15.11	12.93	13.34	7.52	0.001
VAL (mm)	59.54	61.67	57.26	9.75	< 0.001

***One way ANOVA**

Table 19: Comparison of hyoid position related parameters between subjects with Normal, Class I and Class II occlusion baseline (mm)

Variable	Normal subjects	Class I subjects	Class II subjects	F value*	p value
HRGN (mm)	36.95	34.30	36.41	3.05	0.05
HH1 (mm)	3.16	3.58	2.73	0.75	0.47
C3H (mm)	39.00	38.18	34.79	8.22	< 0.001
SH (mm)	97.23	91.74	93.85	5.85	0.004

***One way ANOVA**

Table20: Comparison of hyoid position related parameters between subjects with Normal, Class I and Class II occlusion post treatment (mm)

Variable	Normal subjects	Class I subjects	Class II subjects	F value*	p value
Mean HRGN (mm)	36.95	35.34	36.03	1.01	0.36
Mean HH1 (mm)	3.16	3.95	2.24	3.12	0.05
Mean C3H (mm)	39.00	37.29	35.73	4.44	0.01
Mean SH (mm)	97.23	93.04	92.66	4.96	0.01

***One way ANOVA**

Table 21– Changes In Airway dimension And Hyoid bone position – Based On Gender

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pns-R pre	Equal variances assumed	3.561	.075	-.164	18	.871	-.1261	.76772
	Equal variances not assumed			-.174	15.970	.864	-.1261	.72524
Pns-R post	Equal variances assumed	3.899	.064	-.040	18	.969	-.030	.7606
	Equal variances not assumed			-.042	15.818	.967	-.030	.7175
Pns-Ad1 Pre	Equal variances assumed	1.348	.261	.220	18	.828	.1231	.55934
	Equal variances not assumed			.215	15.078	.833	.1231	.57335
Pns Ad1 Post	Equal variances assumed	2.126	.162	.016	18	.988	.010	.6120
	Equal variances not assumed			.015	13.513	.988	.010	.6371
SPP-SPPW Pre	Equal variances assumed	.423	.524	.365	18	.719	.1687	.46185
	Equal variances not assumed			.358	15.609	.725	.1687	.47086
SPP-SPPW Post	Equal variances assumed	.577	.457	-.039	18	.969	-.0200	.50748
	Equal variances not assumed			-.039	15.847	.970	-.0200	.51609
U-MPW Pre	Equal variances assumed	.449	.511	-.457	18	.653	-.2029	.44395
	Equal variances not assumed			-.456	17.002	.654	-.2029	.44537
U-MPW Post	Equal variances assumed	3.864	.065	-1.296	18	.211	-.6929	.53466
	Equal variances not assumed			-1.215	11.139	.250	-.6929	.57037
TB-TPPW Pre	Equal variances assumed	.962	.340	.293	18	.773	.1289	.43971
	Equal variances not assumed			.301	17.942	.767	.1289	.42767
TB-TPPW Post	Equal variances assumed	.482	.497	.167	18	.869	.0731	.43879

	Equal variances not assumed			.161	14.297	.874	.0731	.45327
V-LPW Pre	Equal variances assumed	.114	.739	.683	18	.503	.4279	.62611
	Equal variances not assumed			.681	16.995	.505	.4279	.62815
V-LPW Post	Equal variances assumed	.700	.414	.680	18	.505	.4372	.64329
	Equal variances not assumed			.685	17.675	.502	.4372	.63811
VAL pre	Equal variances assumed	.040	.843	.190	18	.852	.121	.6395
	Equal variances not assumed			.192	17.889	.850	.121	.6306
VAL Post	Equal variances assumed	1.491	.238	.752	18	.462	.460	.6118
	Equal variances not assumed			.729	14.553	.477	.460	.6304
H-RGN Pre	Equal variances assumed	1.250	.278	-.350	18	.730	-.2042	.58284
	Equal variances not assumed			-.334	12.860	.743	-.2042	.61064
H-RGN post	Equal variances assumed	.404	.533	.380	18	.708	.2295	.60341
	Equal variances not assumed			.374	15.862	.713	.2295	.61356
HH1 pre	Equal variances assumed	.536	.474	-.756	18	.459	-.2783	.36802
	Equal variances not assumed			-.761	17.579	.457	-.2783	.36579
HH1 Post	Equal variances assumed	1.801	.196	-1.875	18	.077	-.5480	.29233
	Equal variances not assumed			-1.947	17.563	.068	-.5480	.28150
C3H pre	Equal variances assumed	.041	.843	-.248	18	.807	-.1432	.57772
	Equal variances not assumed			-.248	17.147	.807	-.1432	.57837
C3H Post	Equal variances assumed	.028	.869	-.797	18	.436	-.420	.5266
	Equal variances not assumed			-.802	17.602	.433	-.420	.5232
SH pr	Equal variances assumed	1.725	.206	-.588	18	.564	-.8432	1.43360
	Equal variances not assumed			-.571	14.667	.576	-.8432	1.47551
SH post	Equal variances assumed	2.796	.112	-.532	18	.601	-.706	1.3264
	Equal variances not assumed			-.507	12.719	.621	-.706	1.3916

Discussion

Pharyngeal airway dimensions, narrowing of pharyngeal passage and hyoid bone positions are of interest in orthodontics. Several studies have indicated that there are significant relationships between pharyngeal dimensions and craniofacial abnormalities.

Nasopharyngeal airway area increases rapidly until 13 years of age and after this the growth slows down. An inactive period of growth in pharyngeal structures has been reported beyond 15 years of age.[16,82,42,51,59] . Chang min et al [15] reported the developmental changes on pharynx and hyoid position. By 3 years of age the hyoid lies at a level between 3rd and 4th cervical vertebrae and descends to the level of the 4th vertebrae at adulthood. Later during growth the relative position of the hyoid remains constant.[14,74] . Literature findings indicate that growth may have little effect if any on the sagittal depth of the pharyngeal airway.

This study was performed to evaluate the changes in the pharyngeal airway dimensions and the hyoid bone position following nonsurgical orthodontic treatment in class I and class II subjects with moderate to severe crowding and compared with normoocclusion using lateral cephalometric radiograph. In the present study subjects of 18 – 25 years of age were evaluated.

As this analytical study was retrospective in nature, direct assessment of the respiratory pattern for individual patient was not possible. The medical history and dental history recorded in the clinical orthodontic records were analysed for the criteria for selection of the subjects. Prior history about tonsillectomy and respiratory infections were considered. Any one of these factors could have been related to respiratory obstructions [44, 62]. Patients with a positive history of airway obstructions and other craniofacial abnormalities were excluded from the study. All the subjects in this study had normal BMI and were treated with extractions followed by straight wire appliance 0.022" Roth prescription.

Husamettin Oktay [36] and Hiroyuki Ishikawa et al [35] reported that ANB angle was considered to be the reliable indicator of the anteroposterior skeletal discrepancy. Although clinical significance and reliability of the ANB angle to determine the anteroposterior jaw relationship was argued in the literature, it is still a widely used method to describe anteroposterior dentofacial discrepancies and thus was the measurement of choice for this study to group the subjects. In our study, subjects with ANB angle between 2-4º were included in Class I group and subjects with ANB angle 5-7º were included in Class II group.

Normal respiration is dependent on sufficient anatomical dimensions of the airway. Many studies have contributed to the knowledge that variations in the skeletal pattern could lead to upper airway obstruction.[55]

The pharyngeal airway is an irregular lumen. Narrowing in one or more segments of the airway may induce breathing as well as sleeping problems like obstructive apnoea. Cross sectional area is a better indicator than volume with which to evaluate change in the size of the pharyngeal airway. The size of the pharyngeal airway on lateral cephalograms can be measured as the depth and height in the sagittal plane. So there is an inherent limitation of the study as pharyngeal airway is a three-dimensional structure and it can only be evaluated two dimensionally on lateral cephalometric films. However, Miles *et al.* reported a high reliability of cephalometric landmarks and measurements [60] .

Aboudara et al [13] showed that the resistance to airflow is related to airway size as well as form. So if the airway has a large volume but is bent, then the airway resistance could greatly affect respiration. An airflow test, nasoendoscope examination, nasal resistance measures, lateral cephalograms , Magnetic Resonance Imaging, Computed tomography, Cone Beam CT are used for diagnosing nasal obstruction. Lateral cephalograms particularly have been a very helpful tool because of their simplicity, low cost, and reproducibility[13, 67]. In our study, lateral cephalograms were used to analyse the pharyngeal airway dimension and hyoid bone positions.

The process of converting the analogue information into digital form is called digitization. Quantitative, systematic, and objective measurements based on hard and soft tissue landmarks determined on cephalometric films are used in orthodontics as a valuable tool in orthodontics. Korkmaz Sayinsu et al [46] and Cleomar Donizeth Rodrigues et al [17] confirmed that there was no statistically as well as clinically significant difference in the tracings between digitized cephalograms, direct digital and conventional methods. In the present study lateral cephalograms were digitized using Canon D520 Mf scanner and analysed using Ax Ceph version 2.3.0.74 software.

Mergen D.C and Jacobs R.M[20] in their study measured the size of nasopharynx (upper pharyngeal airway); and compared it between those with normal Class I occlusion and Class II malocclusion. They concluded that the midsagittal nasopharyngeal area was significantly greater in subjects with normal class I occlusion than in those with Class II malocclusion. Oscar Martin et al[65] tried to describe the nasopharyngeal patterns in patients with ideal occlusions and found that nasal fossa, cranial base, and adenoid tissue were larger in men than in women. However, Marcos Roberto de Freitas et al[53] did not find any correlation between the upper pharyngeal airway in Class I and Class II malocclusion types; but concluded that those with vertical growth pattern have narrower upper airway dimensions.

In this pharyngeal dimension study, Class I and Class II malocclusion (skeletal and dental) subjects with crowding grades from 4 to 10 mm[69] analysed from the models (Little's irregularity index – moderate to severe) were included and compared with normoocclusion subjects.

All subjects in this group were treated with extraction of four first premolars. In class II group all subjects were treated with extraction of two maxillary first premolars and two mandibular second premolars .The extraction space was utilized for correction of crowding and mild proclination.

A significant correlation was observed among the extent of central incisor retraction, the amount of hyoid retraction in the horizontal direction, and the change in the cross-sectional area of the hypopharynx[85]. The main reason for the narrowing of the hypopharynx may be the retraction of the hyoid, which was caused by the retraction of the central incisor. Previous studies have shown a possible relationship between hypopharynx and skeletal structures, soft tissues, and musculature.[55, 78].

In the present study, changes in the nasopharynx, velopharynx, glossopharynx and hypopharynx dimensions and hyoid bone positions were measured according to the methods followed by Zhe zhong et al [87] and Alan Lowe et al[1]. These changes were compared with the normoocclusion control group.

The mean differences in the dimensions of nasopharynx, velopharynx, glossopharynx and hypopharynx of Class I group and Class II Group following orthodontic treatment were compared (Table 7 and Table 10).

In our study, there was a significant overall reduction in the pharyngeal airway after orthodontic treatment in Class I group. Compared to the palatopharynx and oropharynx, the cross sectional areas of glossopharynx and hypopharynx were significantly reduced (p value 0.001) more after the treatment. Nasopharynx and oropharynx were reduced by 0.26mm and 0.6mm respectively whereas glossopharynx and hypopharynx were reduced by 0.73mm and 1.14mm respectively. These findings were coinciding with the results of the study by Qingzhu Wang [70], Derya Germec-Cakan et al[22], and Yu Chen[85] . This amount of decrease cannot be explained by growth changes and might be due to narrowing of the tongue space after incisor retraction.

But our results differed from the result of a study by Valiathan et al [52] in which they demonstrated that oropharyngeal volumes did not show significant change after orthodontic treatment with extraction of four premolars in adolescents. This negative finding may be attributed to mandibular growth as their study group had subjects in the age range of 11 – 13 years and the high variability of oropharyngeal volume.

However, in our study, it was not the same in case of Class II group. The nasopharyngeal airway dimensions were reduced after treatment significantly (p value 0.002) but the velopharynx, glossopharynx and hypopharynx areas were significantly increased by 1.05mm , 1.29mm and 2.31mm respectively (p value 0.001) following treatment. A possible explanation for this increase in airway might be an increase in posterior tongue space after forward movement of mandible due to the use of orthodontic mechanotherapy for Class II corrections. The average mesial molar movement was 3.23 mm (TABLE 12) in this group.

The importance of hyoid bone lies in its distinctive relationships. It has no bony articulations but provides attachment for muscles, ligaments, mandible, fascia of the pharynx and cranium [29, 73]. A close association of the hyoid bone to the cartilages of the larynx also suggests the importance of hyoid in the performance of both respiration and deglutition. The anteroposterior position of the hyoid bone follows the anteroposterior position of the chin. When the mandible was rotated in counter clockwise direction, the suprahyoid muscles pulled the hyoid bone to move into a more anterior position, and when the mandible was rotated in a clockwise direction, the hyoid bone moved posteriorly.

Yu Chen et al[75] and Qingzhu Wang et al[85] demonstrated a significant change in position of hyoid bone following orthodontic treatment in Class I bimaxillary protrusion cases. The hyoid bone was retracted postero inferiorly after treatment. Masayoshi Kawakami et al[55] confirmed that the vertical and horizontal spaces around the tongue were maintained postoperatively with the backward and downward movement of the hyoid, which compensates for the reduction in oral volume after mandibular setback surgeries. The hyoid position depends on the relative balance of muscle attachment from the base of the cranium bilaterally and the region of the mandibular symphysis[14].

The mean differences in the hyoid bone positions of Class I group and Class II Group following orthodontic treatment were shown in table 8 and table 11.

In our study, there was a significant change in the hyoid position in relation to the point RGN (Retrognathion), Third cervical vertebra (C_3) and Sella point in both Class I and Class II groups. The hyoid bone was found to be retracted postero inferiorly in Class I group. The amount of retraction was 1.04 mm and 1.30 mm in horizontal and vertical direction (Table 8). Findings of our study were coinciding with that of the study by Qingzhu Wang [70]. The inferior movement of the hyoid bone seen in the present study was consistent with the findings of other studies, showing that this movement is an adaptation preventing an encroachment of the tongue into the pharyngeal airway [85]. Our findings confirmed that the horizontal spaces around the tongue (TB-TPPW) were decreased with the downward movement of the hyoid bone caused by the retraction of incisors. But in class II group of our study the hyoid bone was found to be shifted antero superiorly.

Comparison of the airway dimensions and hyoid positions of Class I and Class II to the normoocclusion subjects reveals the following:

Pretreatment nasopharynx and velopharynx areas of class I and class II subjects were wider than the normoocclusion subjects. But the hypopharynx area was constricted in both Class I and Class II groups with highly significant reduction in Class II groups which is attributable to the retrognathic mandible and posteriorly positioned tongue. Vertical length of the airway was also reduced in Class II group in comparison with that of Class I group and normoocclusion group.

After treatment the overall pharyngeal space was significantly reduced in Class I group, with only velopharynx and glossopharynx areas approximating to the values of the normoocclusion group. Whereas in Class II group, there was a significant widening of the velopharynx, glossopharynx and hypopharynx areas attributable to the forward positioning of the mandible after the treatment which may be due to the orthodontic mechanotherapy to correct class II condition which includes the use of inter arch elastics or protraction of molars or fixed functional appliance during treatment. Whereas the hypopharynx area was not widened to the normal levels.

At baseline the Hyoid bone was positioned antero superiorly in Class I subjects and postero superiorly in class II subjects when compared to the normoocclusion groups. After treatment the hyoid was retracted postero inferiorly in Class I group attributable to the constriction in lower airway. Whereas in class II group the hyoid bone was shifted anterosuperiorly after treatment which can be attributed to the forward movement of mandible due to the orthodontic mechanotherapy to correct class II condition which includes the use of inter arch elastics or protraction of molars or fixed functional appliance during treatment. The changes were statistically significant in both the conditions with p values less than 0.05.

There was no statistically significant (p value > 0.05) sexual dimorphism in the changes of pharyngeal airway dimensions and hyoid positions of the study groups.

Summary and Conclusion

Pharyngeal airway dimension plays an important role in dentofacial development. The malocclusion type and sagittal jaw relationship had been proved to affect the pharyngeal airway dimensions in healthy subjects with average growth pattern. This study had been undertaken to correlate subjects with normal respiratory function with Class I and Class II malocclusions.

- ❖ There was a significant difference in the changes in the airway dimensions and hyoid bone position between Class I and Class II groups following non-surgical orthodontic treatment.
- ❖ Pretreatment nasopharynx, glossopharynx and velopharynx areas of Class I and Class II malocclusion subjects were marginally wider than the normoocclusion subjects. But the hypopharynx area was significantly constricted in both Class I and Class II groups with highly significant reduction (p value < 0.001) in Class II groups.
- ❖ In Class I malocclusion group there was a significant decrease in overall upper airway dimensions, with more reduction in glossopharynx and hypopharynx areas following non-surgical orthodontic treatment with only velopharynx and glossopharynx areas approximating to the values of the normoocclusion group.
- ❖ Unlike in Class I malocclusion group, Class II malocclusion group revealed diverse changes in airway dimensions after orthodontic treatment. Nasopharynx was constricted minimally and the glossopharynx and

hypopharynx areas were widened significantly. Whereas the hypopharynx area was not widened to the level of normoocclusion group.

- Pretreatment Hyoid bone position was antero superior in Class I subjects and postero superior in Class II subjects when compared to the normoocclusion groups. After treatment the hyoid was retracted postero inferiorly in Class I group. Whereas in Class II group the hyoid bone was shifted anterosuperiorly after treatment. Still the hyoid position was not approximated to that of normoocclusion group.
- There was no statistically significant (p value > 0.05) sexual dimorphism in both pharyngeal airway dimensions and hyoid bone positions in all three groups.

Future prospects:

- Further studies may be aimed at long-term effects of nonsurgical orthodontic treatment on pharyngeal airway and hyoid positions.
- It was evident that non-surgical orthodontic therapy has an effect on pharyngeal airway dimensions. Future studies may be carried out to evaluate the changes in airway dimensions following surgical orthodontic therapy.
- Future studies may be done to evaluate the airway flow capacity in different malocclusions using 3D imaging systems.

Bibliography

1. **Alan A. Lowe, Takashi Ono, D Kathleen A. Ferguson, Eung-Kwon Pae, C. Frank Ryan and John A. Fleetham-** Cephalometric comparisons of craniofacial and upper airway structure by skeletal subtype and gender in patients with obstructive sleep apnea - Am J Orthod Dentofac Orthop 1996;110:653-64.
2. **Allan G. Brodie** - Consideration of musculature in diagnosis, treatment, and retention - Presented at the forty-eighth Annual Meeting Of The American Association Of Orthodontists, St. Louis, Mo., April 23. 1952
3. **Anette M. C. Fransson, Åke Tegelberg, Bjo rn A. H. Svenson, Bertil Lennartsson, and Go ran Isacsson,** - Influence of mandibular protruding device on airway passages and dentofacial characteristics in obstructive sleep apnea and snoring Am J Orthod Dentofacial Orthop 2002;122:371-9
4. **Antje Tallgren And Beni Solow** - Long-Term Changes In Hyoid Bone Position And Craniocervical Posture In Complete-Denture Wearers- Acta Odontol Scand 1984;42:257-267
5. **Armando Gale, Pauli V.J.Kilpelainen, Maija T.Laine Alava** - Hyoid Bone Position After Surgical Mandibular Advancement - European Journal Of Orthodontics 23(2001) 695-701
6. **Ashok Kumar Jena; Ritu Duggal** - Hyoid Bone Position In Subjects With Different Vertical Jaw Dysplasias - Angle Orthod. 2011;81:81–85, 183-214
7. **Ashok Kumar Jenaa; Satinder Pal Singhb; Ashok Kumar Utrejac** - Sagittal mandibular development effects on the dimensions of the awake pharyngeal airway passage - Angle Orthod. 2010;80:1061–1067.

8. **Athanasios E. Athanasiou, , Nick Toutountzakis,, Dimitrios Mavreas, Martin Ritzau, , and Ann Wenzel,** - Alterations of hyoid bone position and pharyngeal depth and their relationship after surgical correction of mandibular prognathism -Am J Orthod Dentofac Orthop 1991 ;100:259-65.
9. **Austin Phoenix; Manish Valiathan; Suchitra Nelson; Kingman P. Strohl; Mark Hans** - Changes In Hyoid Bone Position Following Rapid Maxillary Expansion In Adolescents - Angle Orthod. 2011;81:632–638
10. **Bibby. R. E. and C. B. Preston**- The Hyoid Triangle - Volume 80, Number 1, Am J Orthod July 1981
11. **Bibby R. E.** - The Hyoid Bone Position In Mouth Breathers And Tongue-Thrusters - Am. J. Orthod., May 1984, Volume 85, Number 5
12. **Boon H.Seto, Helen Gotsoloulos, Milton R.Sims, Peter A.Cistulli** – maxillary morphology in obstructive sleep apnoea syndrome - European Journal of orthodontics 23 (2001) 703-714
13. **Cameron Aboudara, Ib Nielsen, John C. Huang, Koutaro Maki, Arthur J. Miller, and David Hatcher** - Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed Tomography - Am J Orthod Dentofacial Orthop 2009;135:468-79
14. **Carmine A.Durzo, Allan G.Brodie** – Growth Behavior Of The Hyoid Bone – July 1962, Vol 32, No 3 Angle Orthodontist
15. **Chang-Min Sheng; Li-Hsiang Lin; Yu Su; Hung-Huey Tsai -** Developmental Changes in Pharyngeal Airway Depth and Hyoid Bone Position from Childhood to Young Adulthood **-** Angle Orthod. 2009;79:484–490.

16. **Chester S. Handelman, George Osborne** – Growth of the nasopharynx and adenoid development from one to eighteen years – vol 46, No. 3, July 1976

17. **Cleomar Donizeth Rodrigues, Márcia Maria Fonseca da Silveira, Orivaldo Tavano, Ronaldo Henrique Shibuya, Giovanni Modesto, Carlos Estrela** - Evaluation of indirect methods of digitization of cephalometric radiographs in comparison with the direct digital method Dental Press J Orthod 2010 July-Aug;15(4):124-32

18. **Craig Fairburn.S , DMD, MD, Peter D. Waite, MPH, DDS, MD, George Vilos, DDS, MS, Susan M. Harding, MD, Wanda Bernreuter, MD, Joel Cure, MD, and Sai Cherala, MD** - Three-Dimensional Changes in Upper Airways of Patients With Obstructive Sleep Apnea Following Maxillomandibular Advancement - J Oral Maxillofac Surg 65:6-12, 2007

19. **Dan Grauer, Lucia S. H. Cevidanes, Martin A. Styner, James L. Ackerman, and William R. Proffit -** Pharyngeal airway volume and shape from cone-beam computed tomography: Relationship to facial morphology - Am J Orthod Dentofacial Orthop 2009;136:805-14

20. **Darrell C. Mergen, Richard M.Jacobs** – the size of nasopharynx associated with normal occlusion and class II malocclusion - Vol 40, No 4 oct 1970

21. **David M. Gobeille, D.D.S., And Douglas C. Bowman, D.D.S.** - Hyoid And Muscle Changes Following Distal Repositioning Of The Tongue - Volume 70, Number 3 Am J Orthod September 1976

22. **Derya Germec-Cakan, Tulin Taner and Seden Akan** - Uvulo-glossopharyngeal dimensions in non-extraction, extraction with minimum anchorage, and extraction with maximum anchorage - European Journal of Orthodontics 33 (2011) 515–520

23. **Emine Kaygısız; Burcu Balos¸ Tuncer; Sema Yu¨ ksel; Cumhur Tuncer; Cem Yıldız** - Effects of Maxillary Protraction and Fixed Appliance Therapy on the Pharyngeal Airway Angle Orthod. 2009; 79:660–667.)
24. **Faruk Izzet Ucar ; Tancan Uysal** - Orofacial airway dimensions in subjects with Class I malocclusion and different growth patterns - Angle Orthod. 2011;81:460–468
25. **Fitin Aloufi, Charles B. Preston, and Khalid H. Zawawi** - Changes in the Upper and Lower Pharyngeal Airway Spaces Associated with RapidMaxillary Expansion International Scholarly Research Network,ISRN Dentistry Volume 2012, Article ID 290964 ;10.5402/2012/290964
26. **Garland Hershey .H , Bruce stewart Donald warren** – Changes in nasal airway resistance associated with rapid maxillary expansion- Am J Orthod. 1976 Mar;69(3):274-84.
27. **Gary Cuozzo and Douglas C. Bowman** - Hyoid Positioning During Deglutition Following Forced Positioning Of The Tongue - Volume 68, Number 5, Am. J. Orthod., November 1975.
28. **Graber TM, Neumann B.** Removable orthodontic appliances. Philadelphia: WB Saunders, 1984: 357-375
29. **Gray's anatomy** ; the anatomical basis of clinical practice.40th edition by Susan Standring 2008
30. **Gundega Jakobsone, Arild Stenvik, and Lisen Espeland** - The effect of maxillary advancement and impaction on the upper airway after bimaxillary surgery to correct Class III malocclusion Am J Orthod Dentofacial Orthop 2011;139:e369-e376

31. **Gunduz Arslan, J Devecioglu Kama, T Ozer and IYavuz -** Craniofacial and upper airway cephalometrics in hypohidrotic ectodermal dysplasia Dentomaxillofacial Radiology (2007) 36, 478–483

32. **Hakan El and Juan Martin Palomo** - Airway volume for different dentofacial skeletal patterns - Am J Orthod Dentofacial Orthop 2011;139:e511-e521

33. **Halise Aydemir; Ufuk Memikog˘ lub; Hakan Karasuc** - Pharyngeal airway space, hyoid bone position and head posture after orthognathic surgery in Class III patients Angle Orthod. 2012;82:993–1000

34. **Hans Holmberg and Sten Linder-Aronson** - Cephalometric radiographs as a means of evaluating the capacity of the nasal and nasopharyngeal airway- American Journal of orthodontics Volume 76, Number 5 November, 1979

35. **Hiroyuki Ishikawa, Shinji Nakamura, Hiroshi Iwasaki and Shinichi Kitazawa -** Seven parameters describing anteroposterior jaw relationships Postpubertal prediction accuracy and interchangeability- Am J Orthod and Dentofacial Orthop 2000;117:714-20

36. **Hosamettin Oktay** - A comparison of ANB, WITS, AF-BF, and APDI measurements - Volume 99 Number 2 - Am. J. Orthod. Dentofac. Orthop. February 1991

37. **Ian milne , Jhon cleal** – Cinefluorographic study of functional adaptation of the oropharyngeal structures -Angle Orthod. 1970 Oct;40(4):267-83.

38. **Ioannis.P.Adamidis and Meropi n. Spyropoulos – The** effects of lymphadenoid hypertrophy on the position of the tongue, the mandible and the hyoid bone. Eur J Orthod. 1983 Nov;5(4):287-94.

39. **Ioannis Kollias, Olaf Krogstad - Adult Craniocervical And Pharyngeal Changes** – A Longitudinal Cephalometric Study Between 22 And 42 Years Of Age. Part II : Morphological Uvulo-Glossopharyngeal Changes - Eur J Orthod 21 (1999) 345-355
40. **James A.McNamara Jr.** Influence of respiratory pattern on craniofacial growth. Angle Orthod, 1981; 51: 269-300.
41. **James A. McNamara, Jr., -** A method of cephalometric evaluation -American Journal of orthodontics - Volume 86, Number 6 December, 1984
42. **Jeans .W. D, J. Fernando, A. R. Maw and B. C. Leighton** - A longitudinal study of the growth of the nasopharynx and its contents in normal children - *British Journal of Radiology, 54,*117-121, 1981
43. **Joanna M.Battagel, Amandeep Johal, Bhik Kotecha** – A cephalometric comparison of subkects with snoring and obstructive sleep apnoea - European journal of orthodontics 22 (2000) 353-365
44. **Katherine W. L. Vig** - Nasal obstruction and facial growth: The strength of evidence for clinical assumptions - Am J Orthod Dentofacial Orthop 1998;113:603-11
45. **Kenneth P. Moses, Pedro B. Nava, John C. Banks** - Atlas of Clinical Gross Anatomy: second edition Philadelphia 2012
46. **Korkmaz Sayinsu , Fulya Isik , Göksu Trakyali and Tülin Arun -** An evaluation of the errors in cephalometric measurements on scanned cephalometric images and conventional tracings European Journal of Orthodontics 29 (2007) 105–108
47. **Kyung-Min Oh; Ji-Suk Hong; Yoon-Ji Kim; Lucia S.H. Cevidanes; Yang-Ho Park** - Three-dimensional analysis of pharyngeal airway form in children with anteroposterior facial patterns - Angle Orthod. 2011;81:1075–1082.

48. **Lee W.Graber** - Hyoid Changes Following Orthopedic Treatment Of Mandibular Prognathism - January 1978, Vol 48, No 1

49. **Lee W. Graber, Robert L. Vanarsdall Jr., Katherine W. L. Vig** orthodontics current priciples and techniques – fifth edition Philadelphia mosby – 2012

50. **Lena Zettergren-Wijk, Sten Linder-Aronson,Britt Nordlander, ,Karin Ågren,Eva Svanborg, -** Longitudinal Effect on Facial Growth After Tonsillectomy in Children with Obstructive Sleep Apnea - World J Orthod 2002;3:67–72.

51. **Luc P. M. Tourne** - Growth of the pharynx and its physiologic implications - Am. J. Orthod. Dentofac. Orthop. - Volume 99 Number 2 February 1991

52. **Manish Valiathan; Hakan El; Mark G. Hans; Martin J. Palomo** - Effects of extraction versus non-extraction treatment on oropharyngeal airway volume - Angle Orthod. 2010;80:1068–1074

53. **Marcos Roberto de Freitas, Nadyr Maria Penteado Virmond Alcazar, Guilherme Janson, Karina Maria Salvatore de Freitas, and José Fernando Castanha Henriques -** Upper and lower pharyngeal airways in subjects with Class I and Class II malocclusions and different growth patterns - Am J Orthod Dentofacial Orthop 2006;130:742-5

54. **Maria Julia Pereira Coelho Ferraz1, Darcy Flávio** - Cephalometric Assessment Of The Hyoid Bone Position In Oral Breathing Children - Rev Bras Otorrinolaringol 2007;73(1):47-52.

55. **Masayoshi KAWAKAMI_, Kazuhiko YAMAMOTO, Masaki FUJIMOTO, Kazuhiko OHGI, Masahide INOUE, Tadaaki KIRITA** - Changes in tongue and

hyoid positions, and posterior airway space following mandibular setback surgery Journal of Cranio-Maxillofacial Surgery (2005) 33, 107–110

56. **Melvin Moss, D.D.S., Ph.D., and Letty Salentijn, D.D.S.** - The primary role of functional matrices in facial growth - Am. J. Orthodontics - June 1969 Volume 55 Number 6

57. **Michael Major. P, Carlos Flores-Mir,b and Paul W. Majorc -** Assessment of lateral cephalometric diagnosis of adenoid hypertrophy and posterior upper airway obstruction: A systematic review - Am J Orthod Dentofacial Orthop 2006;130:700-8

58. **Michael Stepovich .L,** - A Cephalometric Positional Study Of The Hyoid Bone - Volume 51, Number 12 Am J Orthod December 1965

59. **Michael Taylor, Kingman P.Strohl, B.Holly Broadbent** - Soft tissue growth of the oropharynx - Angle Orthod 1996; 66(5) : 393-400

60. **Miles P.G, O'Reilly M, Close J. -** The reliability of upper airway landmark identification-Aus Orthod J.1995Oct;14(1):3-6.

61. **Mirja Kirjavainen; Turkka Kirjavainen** - Upper Airway Dimensions in Class II Malocclusion Effects of Headgear Treatment - Angle Orthodontist, Vol 77, No 6, 2007

62. **Nancy Ung, Jane Koenig, Peter A. Shapiro, Gail Shapiro, Georgina Trask** - A Quantitative Assessment Of Respiratory Patterns And Their Effects On Dentofacial Development – American J of Orthod and Dentofac Orthop - 1990;98:523-32.

63. **Nanda Kishore Sahoo , Balakrishnan Jayan, Sukbir Singh Chopra**, - Evaluation of Upper Airway Dimensional Changes and Hyoid Position Following Mandibular Advancement in Patients With Skeletal Class II Malocclusion The Journal of Craniofacial Surgery & Volume 23, Number 6, November 2012 e623-7

64. **Nonglak Pracharktam, Suchitra Nelson, Mark G. Hans, B. Holly Broadbent, Susan Redline, Carl Rosenberg and Kingman P. Strohl** - Cephalometric assessment in obstructive sleep apnea - Am J Orthod Dentofac Orthop 1996;109:410-9.
65. **Oscar Martin, Leonor Muelas, and M. José Viñasa -** Nasopharyngeal cephalometric study of ideal occlusions - Am J Orthod Dentofacial Orthop 2006;130:436.e1-436.e9
66. **Pirilä-Parkkinen .K, Heikki Löppönen, Peter Nieminen Uolevi Tolonen and Pertti Pirttiniemi -** cephalometric evaluation of children with nocturnal sleep-disordered breathing. **Eur J Orthod. 2010 Dec;32(6):662-71**
67. **Pirila-Parkkinen .K; Heikki Lo¨ppo¨nen; Peter Nieminen; Uolevi Tolonen; Eija Pa¨a¨kko¨; Pertti Pirttiniemi** - Validity of upper airway assessment in children - A clinical, cephalometric, and MRI study - Angle Orthod. 2011;81:433–439.
68. **Proffit** W.R- Equilibrium theory revisited : factors influencing position of the teeth - Angle Orthodontist, Vol 48, no 3 july 1978
69. **Profit W**.R contemporary orthodontics 4th edition St.Louis, Mosby 2007.
70. **Qingzhu Wang; Peizeng Jia; Nina K. Anderson; Lin Wang; Jiuxiang Lin -** Changes of pharyngeal airway size and hyoid bone position following orthodontic treatment of Class I bimaxillary protrusion Angle Orthod. 2012;82:115–121
71. **Robert F. Sloan, Ruel W.Bench, James F. Mulick** – The Application Of Cephalometrics To Cineflurography : Comparative Analysis Of Hyoid Movement Patterns During Deglutition In Class I And Class II Orthodontic Patients – Vol 37, No 1 January 1967
72. **Robert M Ricketts** - Respiratory obstruction syndrome - American journal of orthodontics July 1968 volume 54, no 7

73. **Ronan O'Rahilly, Fabiola Müller,Stanley Carpenter, Rand Swenson -** Basic Human Anatomy – A Regional Study Of Human Structure - 2008

74. **Ruel Bench** - Growth Of The Cervical Vertebrae As Related To Tongue, Face And Denture Behavior - Am. J. Orthodontics, March 1963

75. **Sarwat Memon, Mubassar Fida and Attiya** Shaikh - Comparison of Different Craniofacial Patterns with Pharyngeal Widths - Journal of the College of Physicians and Surgeons Pakistan 2012, Vol. 22 (5): 302-306

76. **Siddik Malkoc, Serdar Usumez,Metin Nur, and Claire E. Donaghy -** Reproducibility of airway dimensions and tongue and hyoid positions on lateral cephalograms Am J Orthod Dentofacial Orthop 2005;128:513-6

77. **Sila Mermut Gokce, Hasan Suat Gokce, Serkan Gorgulu, Seniz Karacay, Eralp Akca, Huseyin Olmez** - Relationship Between Class III Malocclusion And Hyoid Bone Displacement During Swallowing: A Cine-Magnetic Resonance Imaging Study - Korean J Orthod 2012;42(4):190-200

78. **Soonshin Hwang; Chooryung Judi Chung; Yoon-Jeong Choi; Jong-Ki Huh; Kyung-Ho Kim** - Changes of Hyoid, Tongue and Pharyngeal Airway after Mandibular Setback Surgery by Intraoral Vertical Ramus Osteotomy – Angle Orthod. 2010;80:302–308.

79. **Takahashi.S , Ono.T , Y. Ishiwata and T. Kuroda - Breathing modes, body positions, and suprahyoid muscle activity** J Orthod. 2002 Dec;29(4):307-13;

80. **Tomonori Iwasaki, Haruaki Hayasaki, Yoshihiko Takemoto, Ryuzo Kanomi, and Youichi Yamasaki** - Oropharyngeal airway in children with Class III malocclusion

evaluated by cone-beam computed tomography - Am J Orthod Dentofacial Orthop 2009;136:318.e1-318.e9

81. **Tomonori Iwasaki, Issei Saitoh, Yoshihiko Takemoto, Emi Inada, Ryuzo Kanomi, Haruaki Hayasaki,and Youichi Yamasaki** - Evaluation of upper airway obstruction in Class II children with fluid-mechanical simulation Am J Orthod Dentofacial Orthop 2011;139:e135-e145
82. **Verin . E., Tardif C., X. Buffet , J.P. Marie , Y. Lacoume , J. Andrieu-Guitrancourt , P. Pasquis** - Comparison between anatomy and resistance of upper airway in normal subjects, snorers and OSAS patients - Respiration Physiology 129 (2002) 335–343
83. **Yoon-Ji Kim, Ji-Suk Hong, Yong-In Hwang, and Yang-Ho Park** - Three-dimensional analysis of pharyngeal airway in preadolescent children with different anteroposterior skeletal patterns - Am J Orthod Dentofacial Orthop 2010;137:306.e1-306.e11
84. **Yoshihiko Takemotoa; Issei Saitohb; Tomonori Iwasakic; Emi Inadac; Chiaki Yamadaa; Yoko Iwased;Miyuki Shinkaia; Ryuzo Kanomie; Haruaki Hayasakif; Youichi Yamasakig** - Pharyngeal airway in children with prognathism and normal occlusion - Angle Orthod. 2011;81:75–80
85. **Yu Chen; Liu Hong; Chun-ling Wang; Shi-jie Zhang; Cong Cao; Fulan Wei; Tao Lv; Fan Zhang; Dong-xu Liu** - Effect of large incisor retraction on upper airway morphology in adult bimaxillary protrusion patients - Three-dimensional multislice computed tomography registration evaluation - Angle Orthod. 2012;82:964–970

86. **Yuko Shigeta, DDS, PhD, Takumi Ogawa, DDS, PhD, Jaqueline Venturin, DDS, Manuel Nguyen,DDS, Glenn T Clark, DDS, MS, and Reyes Enciso, PhD** - Gender- and age-based differences in computerized tomographic measurements of the oropharynx - Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:563-70

87. **Zhe Zhong; Zhihui Tang; Xuemei Gao; Xiang-Long Zeng** - A Comparison Study of Upper Airway among Different Skeletal Craniofacial Patterns in Nonsnoring Chinese Children - Angle Orthod. 2010;80:267– 274.